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ELECTRONIC TELEVISION

In July of this year we mark the fiftieth anniversary of the date when electronic television was invented by the Russian scientist B.L.Rozing. This remarkable new trend in the construction of television systems developed slowly over the course of the first two decades, due to a number of reasons. The attention of our country's specialists and of the Soviet government organs was brought to bear on these problems at the end of the Twenties, i.e., at approximately the same time as work was begun in this field by several laboratories in Western Europe and the United States. The conditions of this competition were very unequal, since at that time the Soviet electrovacuum industry was still at an embryonic stage of development. Nonetheless, Soviet specialists succeeded in finding original and valuable solutions for many of the problems of logical designs of electronic television transmitting and receiving devices.

Beginning from the theoretical-experimental work on high-vacuum transmitting and receiving television tubes, done at the VEI (1931), and right on down to the present mass production of television sets and construction of television centers, Soviet electronic television has traveled a path of development which has been rich in events, a path in which there have been both temporary setbacks and significant new advances.

At the fiftieth anniversary of its existence, electronic television in our country is at a period of particular boom. In accordance with the decision of the central organs of the party and the government, construction of new television centers is going on in dozens of our largest cities, Soviet industry is producing millions of television receivers, in the laboratories experimental work is being done on color television systems and radio circuit systems for transmitting television over great distances, and many other theoretical and experimental jobs are

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100 being handled.

However, it is incorrect to assume that all is well in this field. Unfortunately the tempo and pace of scientific research work on color television systems is still not sufficient, the receiving apparatus which has been produced is still insufficiently reliable, there are many complaints about the poor service given to owners of television receivers by the repair shops. New types of receiving and transmitting tubes are adopted but slowly. To the present day no positive solution has yet been found for the problem of the training of television specialists, and this question has been raised more than once by participants in the scientific-technical sessions of our society.

New progress in all these fields will be the best confirmation of the triumph of progressive Soviet technical thought and of the advantages of the socialistic organization of the people's economy.

The present issue of the journal presents for the most part articles relating to the various problems of television engineering. For problems which touch on the invention and development of electronic television, the editor suggests turning back to the July issue of the journal Radio Engineering.

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THE ELECTRONIC-OPTIC METHOD OF CHANGING THE SCALE OF A TELEVISION IMAGE*

by

I. I. Tsukkerman

Regular member of the Society

The electronic-optic method of changing the scale of a television image is used in the electronic image orthicon. A section of the transfer of this transmitting tube is transformed into an electronic-optic system with variable enlargement and without the image's being turned. A computation of the electronic-optic system is made. The characteristics of the transmission of small details at the changed scale are brought forward.

1. Introduction

Changing the scale of a television image is usually done by moving the transmitting camera (the "inrush") or by changing the focal length of the optic device. To discretely change the scale (or the angle of view of the television camera) the lenses are changed with the help of a turret. Lens systems with a variable focal length are being more widely used in television equipment; they are relatively complex and expensive optic systems of large bulk and weight (Bibl.1). Some general shortcomings are inherent in the methods of changing the scale of a television image by changing the focal length of the optic device; these are: the necessity of introducing a mechanical or electromechanical control system and the change in the depth of sharpness when the focal length is changed.

*Presented at the All-Union Scientific Meeting of the A.S.Popov Society of Radio Engineering and Electric Communication in Moscow, 10 May, 1956.

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The scale of a television image can be changed by changing the peak-to-peak deviation of the plotting beam of the transmitting tube. The basic shortcomings of this method, which show up particularly when an attempt is made to change the scale within relatively wide limits (for example, to double it), are a rapid weakening of the signal in proportion to the reduction in the peak-to-peak deviation (i.e., when the scale is being enlarged), "burning out" of the target, and a decrease in resolving power.

In image transmitting tubes* there is still another possibility for changing the scale, - by changing the coefficient of enlargement of the electronic-optic system of transfer. This possibility has been realized in the case of the image iconoscope (Bibl.2 and 3). To regulate the enlarging, while keeping the angle of rotation of the electronic image constant (this angle is usually of the order of 40°), we change the magnetic field, redistributing the currents in three sections of the transfer coil.

In the case of the image orthicon, a similar method of regulating the enlarging cannot be used. It is characteristic of this tube that the angle of rotation of the electronic image is close to zero and that not only the photocathode but also the target is located in the magnetic field; the magnetic field in the target area should not be substantially changed, so as not to disrupt the conditions under which the reading beam falls orthogonally on the target. In the case at hand, a section of the transfer should be transformed into a magnetic electronic-optic system with variable enlargement, without rotation of the electric image. The method of constructing and computing such systems, as indicated in a brief essay of the author (Bibl.4), is based on the fact that we simultaneously redistribute the electric and magnetic fields in such a way that the basic (axial) trajectories of the electronic

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*Tubes of this type include the image iconoscope, the image orthicon, and the dissector.

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beams and the lines of force of the magnetic field coincide. In this article, we
100 will examine the properties of a similar electronic-optic system, a method of computing it, and practical methods for discrete and smooth changes of the angle of view of a television camera in the case of the image orthicon.

2. The Electronic-optic System

Let us call basic those trajectories for which the plane of the photocathode serves as the normal plane. Let us introduce the cylindrical coordinates r and Z. Let us denote the axis of the tube by Z, the plane of the photocathode by $Z = 0$, the plane of the target by $Z = Z_1$, the basic trajectory by $r(Z)$, the magnetic field intensity on the axis by $H(Z)$, the potential of the electric field on the axis by $V(Z)$, the potential of the target relative to the potential of the photocathode, which is taken as zero, by V_1, the potential of the accelerating electrode by V_y, the relative distribution of the magnetic field and the potential of the electric field on the axis by $G(Z) = \frac{H(Z)}{H(0)}$ and $\phi(Z) = \frac{V(Z)}{V_1}$, the coefficient of enlargement of the system by $K = \frac{r(Z_1)}{r(0)}$; let us attach the subscript nom to values of corresponding quantities at the nominal enlargement.

A condition sufficient to keep the image from rotating is to satisfy the equation

$$\frac{r(Z)}{r(0)} = \sqrt{\frac{H(0)}{H(Z)}}, \qquad (1)$$

which denotes that, in paraxial approximation, the basic trajectories coincide with the magnetic lines of force. Here the basic trajectories are the same as they would be if there were no magnetic field and only the electric field were acting. Consequently, these trajectories satisfy the equation

$$\sqrt{\Phi}\,\frac{d}{dz}\left(\sqrt{\Phi}\,\frac{dr}{dz}\right)+\frac{1}{4}\,\frac{d^2\Phi}{dz^2}\,r=0. \qquad (2)$$

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The role of the magnetic field in this case consists in focusing the element beams on the suitable basic trajectories. The coefficient of enlargement of such a system is

$$K = \sqrt{\frac{H(0)}{H(Z_1)}}. \qquad (3)$$

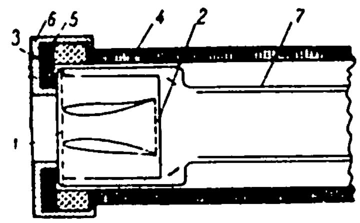

Fig.1

The scale of the image is $M = \frac{K}{K_{nom}}$. Taking into account the fact that the magnetic field in the target area should not be substantially changed when the scale is changed, i.e., $H(Z_1) \approx H_{nom}(Z_1)$, we will obtain

$$M \approx \sqrt{\frac{H(0)}{H_{nom}(0)}}. \qquad (4)$$

For this reason, in order to enlarge the scale we must increase the magnetic field intensity at the photocathode. To do this we insert an additional end coil near the photocathode. This coil is furnished with a magnetic yoke and, in comparison with the focusing coil, has a smaller inside diameter; this allows us to reduce the stray field of this coil in the target area. Alteration of the electric field, necessary for focusing and for eliminating rotation of the image on the target, is accomplished by changing V_1 and V_y.

An electronic-optic system is shown schematically in Fig.1, where (1) is the photocathode, (2) the target, (3) the accelerating electrode, (4) the focusing coil, (5) sections of the end coil, (6) the magnetic yoke, and (7) the focusing electrode.

Solving the problem of the magnetic field of a system without rotation of the image, if the condition of eq.(1) is satisfied, consists in quadratures. Computation of the electric field is simplified, due to the fact that the relative distribution of potential on the axis of the transfer section can be approximated by the

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$$\Phi(Z) = \frac{\operatorname{arc\,tg} \gamma Z}{\operatorname{arc\,tg} \gamma Z_1}, \tag{5}$$

for which eq.(2) is integrated (Bibl.5):

$$\frac{r(Z)}{r(0)} = \Gamma\left(\frac{3}{4}\right) 2^{-\frac{1}{4}} \sqrt[4]{(1+\gamma^2 Z^2)^2 \operatorname{arc\,tg} \gamma Z}\; J_{-\frac{1}{4}}(\operatorname{arc\,tg} \gamma Z) \tag{6}$$

(Fig.2), where γ is the parameter depending upon V_y.

Computation of the fields is done in the following way. We set the values of K_{nom}, $H(Z_1)$ and the required scale M. The coefficient of enlargement in this case will be $K = MK_{nom}$. Then from eq.(6) or from Fig.2 we find the value of γZ_1 at which $\frac{r(Z)}{r(0)}$ will equal K. Knowing γZ_1 and Z_1, we determine γ, and consequently we also determine $\phi(Z)$ from eq.(5) and $\frac{r(Z)}{r(0)}$ from (6) (or else with the help of Fig.2, by replacing the independent variable). Then from eq.(1) we find G(Z), and from eq.(4) we find the value of H(0), and in the same way we determine that H(Z) = H(0)G(Z). The value of V_1 at which focusing is attained on the target is determined from the equation*

$$\frac{H^2(0)}{V_1} = \frac{8m}{c} \frac{n^2\pi^2}{\left|\int\limits_0^{Z_1} \frac{G(Z)}{\sqrt{\Phi(Z)}} dZ\right|^2} \approx$$

$$\approx \frac{448\, n^2}{\left|\int\limits_0^{Z_1} \frac{G(Z)}{\sqrt{\Phi(Z)}} dZ\right|^2} \tag{7}$$

$$(n = 1, 2 \ldots).$$

The case n = 1 corresponds to the first image, and n = 2 to the second image,

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*See Bibl.4. The coefficient in the second equation is chosen so as to express H(0) in oersteds, V_1 in volts, and Z_1 in centimeters.

when one intermediate image is set up between the photocathode and the target.

As an example, in Fig.3 we have shown $G(Z)$ and $\Phi(Z)$ for the practically in-

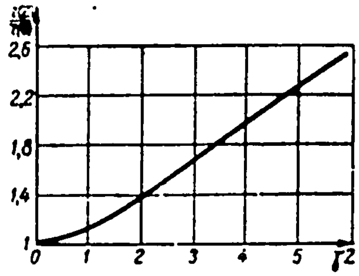

Fig.2

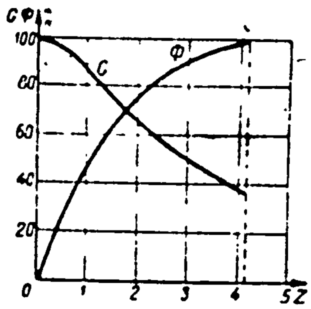

Fig.3

teresting case of $K_{nom} = 0.82$, $H(Z_1) = 65$ oersteds, $M = 2$. When $n = 1$, we obtain $V_1 = 1200$ v; when $n = 2$, $V_1 = 300$ v. If discrete doubling of the scale is required, we must take $n = 2$, since in this case the value of V_1 is near nominal.

In practice, in order to eliminate rotation, merely approximate fulfillment of the condition expressed by eq.(1) - that the basic trajectories and the magnetic lines of force coincide - turns out to be sufficient. By regulating the potential on the accelerating electrode we can attain a state where torsion of the trajectory on the one section is compensated for by torsion of the opposite sign on the other. However we must always strive to assure the most accurate possible coinciding, especially in the area of the photocathode, in order to reduce aberrations. The system illustrated schematically in Fig.1 permits us to reproduce the required electric and magnetic fields with an approximation that is sufficient in practice.

From eq.(4) follows that

$$H(0) - H_{nom}(0) \approx H_{nom}(0)(M^2 - 1). \qquad (8)$$

The expression in the left-hand part of the equation is in proportion to the current of the end coil I_T. Consequently, when the scale of the image is changed, we must change I_T in proportion to $M^2 - 1$. From eq.(7) we may obtain an approximate equation for V_1 depending upon the scale of the image,

$$V_1 \approx V_{1\,min} + \alpha(M^2 - 1) + \beta(M^2 - 1)^2, \qquad (9)$$

where α and β are any positive parameters which in the first approximation do not depend upon M. In accordance with the approximately linear law a slight change is made in the voltage V_f between the focusing electrode and the target when M is changed. Approximate computation of $V_y(M)$ turns out to be considerably more complicated.

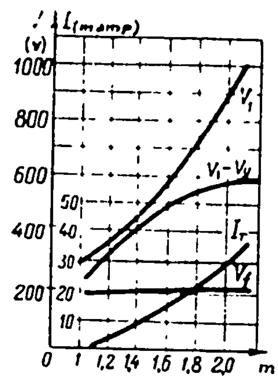

Fig.4

In practice, however, there is no need of such computation, since $I_T(M)$, $V_1(M)$, $V_y(M)$ and $V_f(M)$ are found directly by experiment. In this case the scale is fixed by the current of the end coil, and rotation of the image is corrected in the basic selection of the accelerating electrode potential; for focusing the image a change is made in the voltage between the photocathode and the target. In addition, as a result of some effect had by the stray field of the end coil upon the reading beam, we must change the potential of the focusing electrode. In discrete scale changing, the appropriate conversions are made simultaneously.

For smooth scale changing the indicated voltages and the current of the end coil should be changed simultaneously. The aspect of the curves of $I_T(M)$, $V_1(M)$, $V_y(M)$, and $V_f(M)$ depends on the structure of the electronic-optic system and the position of the coils in relation to the tube. The character of these curves for one of the experimental systems is shown in Fig.4, where $V_1 - V_y$ is the voltage between the accelerating electrode and the target. The tolerances for these quantities are such that it is possible in practice to reproduce the suitable parameters

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with the help of a comparatively simple procedure*.

3. Signal and Transmission of Fine Details when the Scale is Changed

When the enlargement of a transfer system is changed, the photo-current which goes onto the image element is reduced in proportion to the used area of the photo-cathode. However, as a result of a sharply expressed non-linearity in the image orthicon's light-signal characteristic, the drop in the signal when the scale is changed may be relatively small. When there is "working" intensity of illumination on the photocathode and the coefficient of enlargement is doubled, in comparison with the nominal, the signal usually drops 20 to 30%.

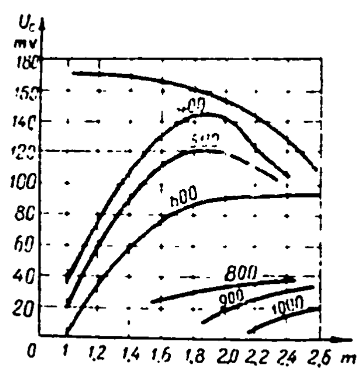

Fig.5

Transmission of fine details of the image improves noticeably when the scale is enlarged by the electronic-optic method.

In Fig.5 we have shown a typical example of how the signal of an image of fine details depends upon the scale. The upper curve corresponds to the full signal (coarse details). The numbers on the curves show how many black and white lines of the optic mira (the experimental table) fit in the height of a frame of the nominal image.

When the scale is enlarged chromatic aberration and the effect of the deflecting system's stray fields are reduced due to the fact that the intensity of the fields increases; however, curvature of the image field may increase. In addition,

*Such a procedure has been worked out by V.P.Abakumov. In this procedure, regulation of the scale is done by turning a single handle.

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when the enlargement is great the end coil's stray field in the area of the target may acquire a noticeable value. This leads to the reduction of reading beam's swing of deflection and to disruption of the conditions under which this beam falls orthogonally on the target.

For further enlargement of the scale and improvement of the transmission of fine details, lengthening a section of the image may turn out to be useful. In an experimental tube in which the distance between the photocathode and the target was more than two times greater than the usual, we have succeeded in obtaining a change of scale in a ratio of 5 : 1 without rotation of the image and with noticeable improvement in the transmission of fine details. In this case, however, the intensity of illumination on the photocathode had to be substantially increased.

4. Concluding Remarks

The electronic-optic method of changing the scale of a television image may find application in cases where it is undesirable or impossible to make use of other methods - the inrush, change of object-lenses, or a vari-focal optical device. In addition, the electronic-optic method may be used in conjunction with these methods. This will allow us to broaden the limits of image scale changing. The principles of the construction and computation of the electronic-optic system, developed here in their application to the image orthicon, are applicable in other cases as well. So, for example, we may construct a magnetic electronic-optic converter without rotation of the image and with an enlargement which is not a unit, - or a transfer section for a new type of image orthicon which has an increased target. There are grounds for assuming that aberrations in such electronic-optic systems, where the basic trajectories coincide with the magnetic field's lines of force, will be relatively small.

In conclusion the author expresses his gratitude to L.D.Aksyenova, V.P. Akhremtsev and G.G.Goncharova, who did a great deal of measuring, and to N.V.

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Dunayevskaya and S.A.Tsukanova, who prepared and studied the experimental tubes.

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VIDEO-RECORDING

As a Discussion

by

M. O. Gliklikh and

M. I. Tsiklis

This is an examination of the principles of construction of systems of television recording and the optimum variants of such systems.

1. Introduction

With the broadening of the television broadcasting network the problem of preserving television transmissions is becoming one of the most essential problems in television.

The development and installation of a video-recording system will make it possible quickly to solve the problem of central television broadcasting by reproducing in the peripheral television centers the programs of Moscow television. Even with television retransmission lines, the reproduction of recordings of Moscow transmissions will remain the basic type of central broadcasting for remote areas where direct reception of television broadcasts from Moscow is inconvenient because of the considerable difference in time.

The use of a system for preserving television programs will permit exchange of programs between television centers and will create the possibility of considerably improving the quality of broadcasting.

Work has not yet been fully completed on a system which permits making a continuous magnetic recording of a signal frequency spectrum of up to 5 mc over the course of an extended length of time.

When an attempt is made to divide the frequency spectrum into several sections and make a parallel recording of them, the complexity of the magnetic recording apparatus is somewhat reduced, but considerable difficulties crop up in correcting the frequency and phase distortions at the joints of the separate sections.

Photographic recording is at the present time the basic method assuring practical application of an apparatus for video-recording.

The devices for preserving television programs which have been developed up to now solve the problem by the method of photographing the image from the screen of the television tube. In this method the recording may be done automatically, without changing the conditions of the television transmission. Inherent in this method is a certain deterioration in the quality of the television image; when the video-recording is reproduced this may be corrected to a considerable extent in an electric channel.

Instead of photographing the television image, direct filming may be done in the television studio. This way the best image quality is obtained, since errors brought in by the channel are eliminated. However, carrying out this type of video-recording is unreasonable due to the following reasons:

1. The integral and spectral sensitivity of the transmitting tube and the photographic film are different. Television transmission can be accomplished when the intensity of illumination on the object is in tens of luxes, but for satisfactory filming of the same object the required intensity of illumination is on the order of hundreds of luxes. This excludes the possibility of making recordings of actual transmissions from the theaters.

2. In focusing one and the same image of an object on the photocathode of a transmitting tube and on the frame surface of a filming device, a parallax is obtained.

3. It is impossible to register directly on cinematographic film the production version of the transmission, as it is accomplished by television methods (fading,

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cinematographic insets, etc.).

4. The cost of using such a method of preserving transmissions is high, since by its very nature it uses up motion picture film rapidly and does not permit subsequent regulation of the quality of the broadcast.

For these reasons studio filming of television programs, originally practiced in some television centers, has been replaced by recording done from the screen of the receiving television tube.

Registering images in this case may be done:

a) while the film moves continuously in the recording apparatus. In this case exposure is made continuously. Impression of the television image on the film is obtained as a result of agreement between the speed at which the film is drawn along and the television scanning, or else with optic "stopping" of the film frame which is being exposed;

b) while the movement of the film is discontinuous. Here exposure is made on a stationary film, which is drawn along in jumps after exposures of the television frame.

2. Systems for Recording on Continuously Moving Film

When such a method of photographing is used with crossline scanning, difficulties crop up in registering the scanning. The scanning of a television field should cover an amount which corresponds to half the frame pace of the motion picture film. Then if the film is drawn along evenly the lines of the odd field will be registered on the entire height of the motion picture frame. Since in the beginning of the exposure of the next, the even, field the film will have been moved along half a frame pace, the lines of this field will be registered between the lines of the odd field through a second object-lens, placed alongside the first. To keep the first object-lens from lighting up the still unexposed section of the film at this time, its light stream is covered up with an obturator. The same thing is done with the light stream of the second object-lens when the image of the odd lines is being

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registered through the first object-lens (Fig.1). If we register the image through only one object-lens, we may avoid the distortions which crop up due to the parallax when the image is split by two object-lenses. But in this case the position of the scanning pattern must be moved by jumps across the screen of the tube after each field is finished. As a result of the difficulty of assuring the same focusing and linearity on the different sections of the screen of the television tube, this system has not been put into application.

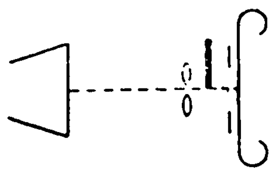

Fig.1

The rigid requirements for accuracy in frame scanning in television systems with intermittent scanning lead in turn to stiff requirements for the conveying mechanism to move the film along smoothly.

In order to keep the lines from overlapping each other more than 10% the relative variation in the speed of the film should not exceed

$$\frac{\Delta v}{v} \quad \frac{0,1}{27} \quad 0{,}008\%.$$

and this is difficult to attain. Here v is the speed of the film movement, and Z is the number of scanning lines.

The basic shortcoming of systems in which the movement of the film is linked with the scanning process is the impossibility of making use of the tube's afterglow, which causes a broadening in the lines in the opposite direction from the movement of the film. If we assume a 10-percent broadening in the lines, then with 625 lines on a motion picture frame 16 mm in height we will obtain a broadening of

$$\Delta S \quad 0{,}1 \cdot \frac{16}{625} = 0{,}0025 \ mm.$$

The permissible time of effective afterglow must be not greater than

$$t_{m} = \frac{\Delta S}{v} = \frac{5 \cdot 10^{-6}}{0{,}175} = 5\ \mu sec$$

The low efficiency of a screen with such a short time of afterglow leads to the necessity of obtaining an extremely high degree of brightness in the tube so as to attain the necessary blackening of the film.

We can profit by the afterglow in exposing images on a smoothly drawn film only if the screen image which is being exposed on the film is moved simultaneously with the film in the same direction and at the same speed. Such motion can be realized with the help of a system of mirrors or a polyhedral prism which "follows" the movement of the motion picture frame, i.e., projects the television image on the motion picture frame in such a way that the elements of the image remain stationary in relation to the film during the time the frame is being transmitted.

In compensating for the movement of the film by a rotating prism, the ray of light broken by the prism comes out of the prism parallel to its former direction with a displacement which is in proportion to the angle of rotation of the prism (Fig.2). In this case accuracy in the execution of the mechanisms for conveying the film and for moving the compensating optics is determined by the requirements of the cross-line scanning, and should be very high.

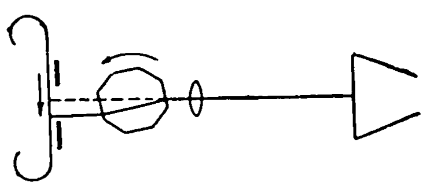

Fig.2

The requirements for stability in frame synchronization in the case of cross-line scanning are distributed between the scanning plan, the mechanism for conveying the film and the movement of the compensating optics. In addition we must take into account the effect of the film's shrinkage upon the evenness with which it is drawn along. The frames which are registered on the film must be rigidly "tied" to the perforation apertures in the film, since the accuracy of the conveyance of the film, and consequently the accuracy of the registration of the frames as well, depends entirely upon the pace of the perforations.

Depending upon storage conditions, unexposed motion picture film may have uneven shrinkage, reducing the perforation pace up to 0.5%. There are mechanical systems which automatically take into account a change in the film's shrinkage and act on the mechanism of film conveyance and of optic compensation. The use of such systems introduces additional difficulties in adjusting and using complex and accurate mechanisms.

However, if there is automatic compensation for change in perforation pace by electro-optic means, then we can considerably lower the requirements for accuracy in the mechanisms of film conveyance and optic compensation. The rigidity with which the registered frames are tied to the perforation apertures is a necessary and sufficient condition for the frames to stand accurately when they are later projected. For this reason a system for additional correction of the image of a frame in its dependence upon the position of the perforation aperture may take into account not only uneven film shrinkage, but also inaccuracies in the execution of the optic compensation mechanism, if the image of a moving, supporting perforation aperture is stopped by the same optic compensator which makes the image of a frame move conjointly with the film.

To accomplish such correction, the perforation must be illuminated by a separate source of light and the light which passes through the aperture must be reflected on the moving optics of the compensator. When the positions of the image of a perforation aperture are appropriate and when a stationary mask is covering it, we obtain signals which are suitable for conducting additional correction of the position of a frame.

In spite of some degree of complexity in such correction, its use leads to considerable facilitation in execution and adjustment of a most efficient

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aggregate, - the optic compensator.

3. Systems of Recording with Intermittent Exposure of Film

In systems employing intermittent film exposure a full television frame is projected on one frame of the motion picture film. The requirements for accuracy in the execution of the mechanism of the filming apparatus are determined in this case not by the conditions of cross-line scanning, but by the filming conditions. Here the necessary frame stopping accuracy of 10 to 15 microns is easily assured by the filming equipment. A sufficiently high sensitivity is obtained in systems such as this. This is explained by the fact that the afterglow is fully taken advantage of. The basic difficulty in constructing a video-recording system in which the film is drawn along in jumps lies in the fact that the change time of the television frame does not correspond to the change time of the motion picture frame.

A time diagram of the operation of the motion picture camera is presented in Fig.3.

As is evident from the diagram, the time during which the obturator is open and the exposure is being made is less than the time it takes to convey the film along.

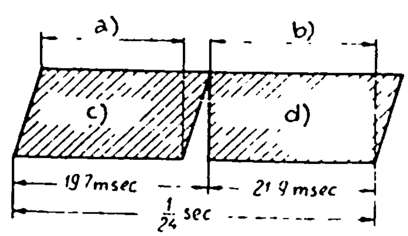

Fig.3

a) Obturator, open; b) Obturator, closed; c) Exposure; d) Movement

The time of exposure is

$$T = \frac{x}{360\,n},$$

where x is the maximum angle of the obturator's opening, and n is the number of frames per second.

In apparatuses of this country the maximum angle of the obturator's opening does not exceed 175°, and the time of exposure T_e equals 19.7 msec; then the time of the film's movement T_{mp} equals 21.9 msec.

The time diagram for the transmission of a television frame in conformity with the television standard is shown in Fig.4.

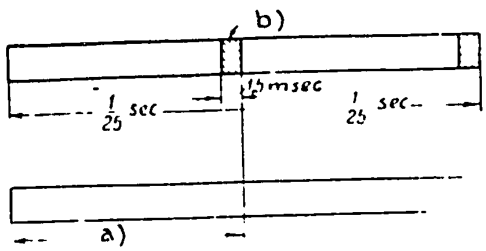

Fig.4

a) Exposure; b) Arresting pulse

The fields of a television image follow one another continuously with an interval of 1.5 msec. Setting up filming equipment with such a movement time presents great difficulties and requires the use of special film made for considerable dynamic stresses. In addition we must take into account the fact that the time of the film movement must be considerably less than the interval between two television frames, since the screen afterglow is taken advantage of in exposure and in order to obtain even brightness in the frame the television frame must continue being exposed on the film until the afterglow of the last lines has ended.

Thus, the conditions of television transmission leave no time for moving the film.

In the intermittent-movement-of-film systems of recording which have been worked out up to now, the change of the motion picture frame is done during the time of transmission of part of the lines or frames of the television image, and these lines or frames are not recorded by the apparatus. This leads to a reduction in the clarity of the recorded image, or to a deterioration in the smoothness with which the images of objects move.

In one of the first installations, developed in England, only the odd fields were taken on the film, and during the even fields the film was drawn along in the apparatus. Thus in these apparatuses the image was recorded with half clarity.

In America recording is done by skipping half a field after the recording of each frame. Here advantage is taken of the fact that the number of television

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frames per second according to the American standard is 30, while the number of

100 motion picture frames is 24 per second.

In one system, proposed in France and most suitable for our television standard, one television field is skipped after the recording of each frame. The time diagram for the operation of an apparatus of this system is shown in Fig.5.

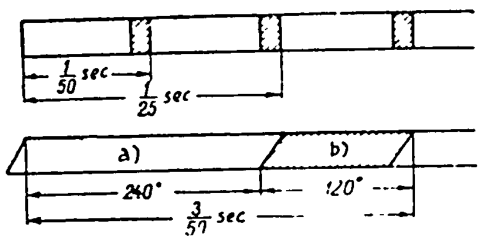

Fig.5

a) Exposure; b) Movement

In this way, 25 television frames are recorded on 16-2/3 motion picture frames; the ready film may be again re-printed in such a way as to use the speed of 25 frames per second, necessary to provide the sound accompaniment.

In view of the fact that such a system is distinguished by its simplicity and may be a matter of practical interest, we have made a qualitative evaluation of motion picture films taken by this method. The majority of observers have noted sharpness and angularity in motions, and this was especially noticeable when objects were moving rapidly and considerably deteriorated the quality of the image.

A more satisfactory method, which permits us to register all the television information, is the use of a television screen with a time of afterglow which is greater than the duration of the transmission of a television field. In this case the film is moved during one field, but the lines of the television image which appear on the tube screen while the film is being moved remain on the screen thanks to the protracted afterglow and are exposed together with the lines of the next field. In this case uneven brightness is obtained in the image over the area of the frame. Brightness of the lines which appear on the screen when the obturator is open will be greater than the brightness of the lines which are exposed "by memory". Because of the afterglow, moreover, uneven brightness will be obtained in STAT the lines of each field. In the field which is exposed "by memory" the brightness of the last lines is greater, while in the next field the brightness of the first lines will be greater.

We may compensate for uneven brightness in a television frame by giving compensating signals to the control electrode of the tube. To do this we must know the law of drop in brightness. So, for example, for phosphors with great afterglow (ZnS or $ZnCd$) which are activated by copper, the law of drop in brightness is defined by the expression

$$B = \frac{B_0}{(1 + At)^2},$$

where $A = 61.5 \text{ sec}^{-1}$.

Since the scanning is linear, it is easy to determine the form of the compensating signals.

The need for correction is the weak point of the system we are examining, since even without such correction the limit range of contrast of the writing tube decreases. The required correction may be reduced by increasing the time of exposure through decreasing the time of the film's movement.

A high degree of evenness in brightness is obtained by using screens with a time of afterglow which exceeds many times over the duration of transmission of a television frame. Here it is necessary to "quench" the screen with a special field in such a way that the screen's glow cease immediately after exposure. Another method, suitable for the Soviet standard and permitting us to fully register all the lines and frames of a television image, is the system of recording with two frame openings.

In this system the image is projected simultaneously on two frame openings. While the film is being exposed in the first opening, it is being drawn along in the second opening behind a closed obturator. Between the two frame openings there is a free loop. In this way the even and odd frames of the recorded film are

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exposed with a displacement of several frames. In order to establish the normal sequence of frames, the recorded film must be re-printed. In order to reduce expense of film, the recording may be done in such a way that four narrow-film frames are recorded on one frame of wide film (35 mm). It is expedient to do the re-printing of the film on the same apparatus on which the recording was done; in this way we eliminate distortions connected with inaccuracies in the setting of the film in each of the frame openings.

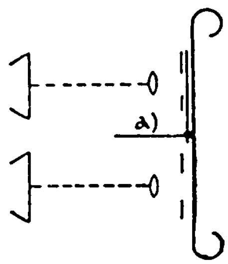

Fig.6

a) Obturator

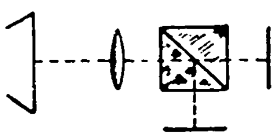

Fig.7

Three methods of recording on two frame openings are possible:

1. With two tubes, from whose screens the image is projected onto two frame openings (Fig.6). With this method the image may flicker with a frequency of 12.5 hc, as a result of the difficulty of obtaining identical images on the screens of both tubes. In view of the fact that such flickers cause unpleasant visual sensations, this method cannot be recommended.

2. Splitting the light stream with the help of a cube with a semi-transparent diagonal (Fig.7).

This method makes it possible to obtain an identical light stream in both frame openings. A shortcoming of this system is the loss of 50% of the light stream in recording.

3. Commutation of the light stream with a mirror obturator (Fig.8). In this case there is no loss of light; however, construction of the film-taking apparatus is complicated.

Experimental checking should show which of the two latter methods must be given preference.

A shortcoming of the last system is the need to complicate the filming part of the apparatus.

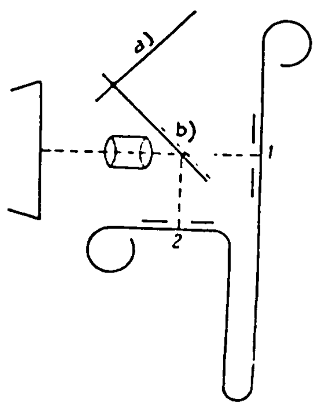

Fig.8

a) Axis; b) Mirror obturator

In summarizing all that has been stated above, we must note that the most promising type of video-recording is magnetic recording.

While taking into account the expedience of the fastest and fullest possible application of a system for preserving television programs, it is expedient to set down, parallel with the continuation of work on magnetic video-recording, the development of the three photographic methods of video-recording, as described in this article, which are potentially suitable for registering on film all the information given in a standard video-signal. These systems are:

1. The system with smooth movement of film and electro-optic compensation for unevenness in the film's pace.

2. The system which takes advantage of the afterglow of the tube.

3. The system with two frame openings.

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ON ONE METHOD FOR OBTAINING HIGH ACCURACY VERTICAL SWEEP

by

L. L. Santo

The author defines the requirements for accuracy in the coinciding of the two rasters in re-recording the television signal. He presents a schematic for a generator with controlled form of voltage and gives experimental data.

1. Introduction and Statement of the Problem

In some color television systems, when simple transmitting cameras with sequential change of colors are used for a compatible television system, we make use of electronic-optic re-recording, which permits the transition from sequential change of colors in the camera and their simultaneous transmission in a channel (for example in the "chromacoder" system). Re-recording the television signal is also an unavoidable operation when some methods of narrowing the spectrum of the television signal are employed.

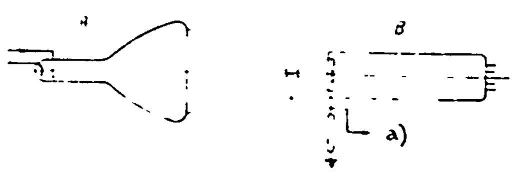

Fig.1

a) To amplifier

In both above-mentioned cases, the signal which is being recorded sets up on the screen of the kinescope A an image which is projected onto the photocathode of the transmitting tube B (Fig.1). Since the image on the screen consists of separate lines, the potential relief on the photocathode also has a line structure. During the counting, the beam of electrons of the transmitting tube should move along the lines of the potential relief. When the lines do not coincide there is a loss of clarity or interference in the form of moire. With conventional sweep oscillators it is impossible to obtain a

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combination of the two rasters so that the moire is fully absent.

The necessity of eliminating interference leads to a sharp increase in the requirements for vertical-sweep oscillators of cathode-ray recording tubes.

These generators should permit the staff to change the interval and form of the lines and at the same time to obtain full compatibility in the rasters. In addition, the generators should possess great operational stability.

2. Determining the Necessary Accuracy in the Coinciding of the Two Rasters

In Fig.2 we have shown one line, traced by the beam of the transmitting tube on the photocathode. Its width is d_1. Here also we have illustrated the corresponding line which is projected from the kinescope screen. Its width is d_2. It is easy to see that the projected line will not go beyond the limits of the line of the transmitting tube if the maximum deviation in the depicted lines which pass through the center of these lines is less than

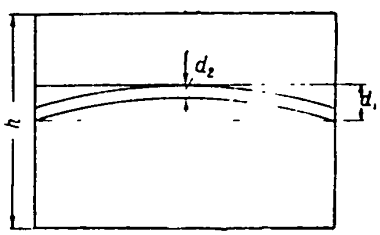

Fig.2

$$\Delta = \frac{d_1}{2}(1 - q), \tag{1}$$

where $q = \frac{d_2}{d_1}$.

Let us assume that d_1 has the maximum permissible value $\frac{h}{Z}$, where h is the height of the frame and Z is the number of lines.

Then from eq.(1) we obtain

$$\varepsilon = \frac{\Delta}{h}\,100\% \quad \frac{1}{2Z}(1 - q)\cdot 100\% \tag{2}$$

We will call the value ε the "scanning inaccuracy".

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As an example let us calculate the scanning inaccuracy for $Z = 625$ and $q = \frac{1}{2}$. We will obtain $\varepsilon \approx 0.04\%$.

With the help of the usual generators it is very difficult to obtain a scanning inaccuracy of less than 1% on the whole raster. From this it follows that the requirements applying to generators of cathode-ray recording tubes should be very stiff, since such generators should assure an inaccuracy approximately 25 times smaller than that of the conventional generator.

3. The Block Diagram of a Sweep Oscillator

Matching the two rasters is difficult to attain because of the fact that the different cathode-ray tubes, depending on their geometry, cause different distortions of the raster. In addition, the form of the raster is affected by the configuration of the deflecting coils and the form of the current passing through them.

Distortion of the raster shows up in the following way:

1) The distances between the lines along a vertical which passes through the center of the frame are not equal;
2) The lines are not rectilinear;
3) The electron beam along a line moves nonuniformly.

Compensating for distortions by changing the configuration of the deflecting coils is made difficult not only due to structural considerations, but also because the geometry and the parameters of the deflecting coils must be selected with consideration of absence of astigmatism over the whole frame. In view of this, there remains only one rational way to compensate for the above-mentioned raster distortions: by correctly selecting the form of the currents in the deflecting coils. The first two types of distortions may be compensated for by correct selection of the law of change of current in a frame generator. If it is necessary to compensate for the third type of raster distortions as well, - and this becomes necessary

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in combining not only the lines, but also the raster elements, - then we must correctly choose the form of the currents in the line generators.

The schematic for a generator for accurate frame scanning should be such that it is possible to regulate the distance between the lines along the central vertical, and the deformation of the lines, independently of one another. In this case we can attain from the beginning the coinciding of the lines near the center vertical, and then, by regulating the deformation of the lines, the coinciding of all points of the raster.

It is expedient to present the current in the deflecting frame coils in the form of the sum

$$I_y = I_{y1}(y) + I_{y2}(x, y),$$

where x and y are the coordinates of the track of the beam of electrons on the target, and are a function of the time.

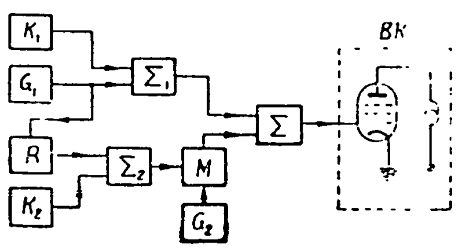

Fig.3

The current $I_{y2}(x, y)$ determines the deformation of the lines and is a function of the two variables x and y. Regulating the form of I_{y2} has no effect upon the distance between the lines along the center vertical (the axis $x = 0$), if for $x = 0$, $I_{y2}(0, y) = 0$. In this case the distance between the lines is determined only by the current $I_{y1}(y)$, which is a function of only the one variable y.

The dependence between the current I in the deflecting coils and the combining of the track of the electron beam on the target may be written in the form of the series

$$I = a_1 r + a_2 r^3 + a_3 r^5 + a_4 r^7 + \dots$$

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It is also possible to construct deflecting systems for which the members of this series decrease so rapidly that members of the higher order, beginning with a_4r^7, may be disregarded.

In this case the current I_{y2} is expressed with a sufficient degree of accuracy in the form of the product of the two functions

$$I_{y2} = x^2 f(y).$$

where f(y) depends upon the constant values a_1, a_2, a_3.

The current generator which feeds the deflecting frame coils should be of such construction that we may select the optimum form of the current I_{y1} and of the envelope curve f(y). The block diagram of such a generator is shown in Fig.3, where BK is the output cascade of the frame scanning generator; G_1 is a generator of sawtooth voltage with half-frame frequency; K_1 is a generator of compensating voltage of controlled form (with the help of K_1 and G_1 we may select the optimal form of the current I_{y1}); G_2 is a generator of parabolic pulses x^2 with the frequency of the lines; P is the potentiometer; K_2 is a generator with controlled form of pulses [with the help of P and K_2 we may select the optimum form of f(y)]; and M is a modulator, in which x^2 is multiplied by f(y).

The most responsible blocks in accurate-scanning generators are the generators with controlled form of voltage pulses, K_1 and K_2. Analysis has shown that it is enough for the voltage of compensator K_1 to contain 5 or 6 harmonics, and for that of compensator K_2 to contain an even lower number of harmonics.

In the different fields of contemporary technology we may come across generators with controlled voltage form (Bibl.1, 2 and 5). To obtain high-accuracy scanning we may use only those which satisfy the following requirement: when a generator's voltage form is changed on one section of a period, the voltage outside this section should remain unchanged or should change inconsiderably.

It is also desirable that the generator satisfy the principle of isoformism,

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i.e., that the form of the oscillations of a voltage generator be in simple linear correspondence with the positions of the generator regulators (Bibl.1); this greatly simplifies the process of adjusting such generators.

4. The Generator with Controlled Voltage Form

In this article we do not deal with the task of evaluating the existing generators with controlled voltage form. For this reason let us examine only the principle of operation of a new generator, the block scheme of which is shown in Fig.4.

The basic elements in this generator are nonlinear transformers whose cores are made of soft magnetic material with pronounced saturation. These cores are best made of ferrite.

When sawtooth current passes through the primary windings of the transformers to the secondary windings, bell-shaped pulses arise. The ampere turns (w_3I_3) of the third magnetizing winding may be selected in such a way that the pulses on the secondary windings of the separate transformers arise consecutively at the same time intervals. The amplitude of the pulses is changed with the help of potentiometers. At the summator output, a series of pulses differing in amplitude is obtained. When these are passed through a filter of lower frequencies, the voltage obtained at the output approaches in form the curve L, which passes through identical points on the arms of the potentiometers. The upper harmonic of this voltage is determined by the filter passband. This generator possesses the property of isoformism.

The isoformism of this generator may be explained in the following manner. When the pulses on the secondary windings of the transformers are sufficiently short and when the frequency band is limited, the voltage at the filter output is essentially formed of a series of pulses (Fig.5).

$$u_k(t) \approx A_k \frac{\sin 2\pi f_c (t - k\Delta t)}{2\pi f_c (t - k\Delta t)}, \qquad (3)$$

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where k = 0, 1, 2, 3..., and f_c is the band of ideal filtration.

If we select the sub-magnetizing ampere turns of the transformers in such a way that the pulses follow one another with the time interval

$$\Delta t = \frac{1}{2f_c}, \tag{4}$$

then the k^{th} pulse will show up just when the voltage from all the other pulses is passing through zero. In this way, their total voltage at the instant $t = k\Delta t$ is determined only by the value of A_k, which is proportional to the resistance R_k of the k^{th} potentiometer (Fig.4).

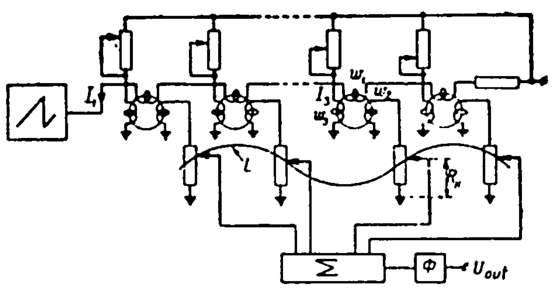

Fig.4

The time lag Δt between the separate pulses must, in addition to satisfying eq.(4), satisfy eq.(5)

$$\Delta t = \frac{T}{N}, \tag{5}$$

where T is the period of the sawtooth current in the primary windings of the transformers, and N is the number of transformers.

The filter band is chosen according to the number of harmonics n, which should contain the output voltage

$$f_c = nf_0, \tag{6}$$

where f_0 is the fundamental frequency.

For simultaneously satisfying eqs.(4), (5), and (6), the necessary number of nonlinear transformers is

$$N = 2n, \tag{7}$$

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since the function $g_k(t)$ returns to zero 2 n times in the time interval T.

The voltage-forming process we have described is essentially the physical application of a direct conclusion based on Kotel'nikov's theorem.

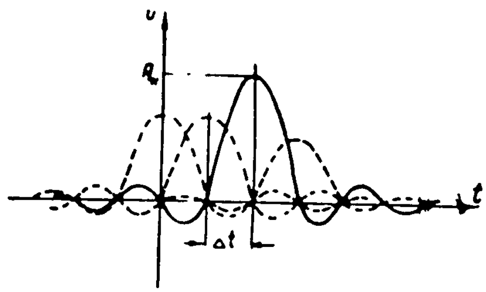

Fig.5

Let us examine in greater detail the pulses which arise on the secondary windings of the transformers. In Fig.6 we show the approximate path of the hysteresis loop of the core; on the abscissa we have plotted the total ampere turns $aw = w_1I_1 + w_3I_3$, and along the ordinate we have plotted the induction (or magnetic flux in the core).

In the secondary winding pulses are created whose value and form are determined by the expression

$$e = w_2 \frac{dF}{dt} = w_2 \frac{\partial F}{\partial(aw)} \frac{d(aw)}{dt}, \qquad (8)$$

where F is the magnetic flux in the core.

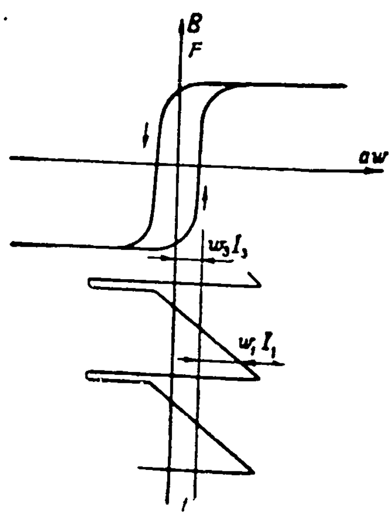

Fig.6

Let us note that $\frac{dF}{d(aw)}$ is a quantity which is proportional to the magnetic permeability μ. In order to ensure re-magnetization of all the cores, the form of the sawtooth current during the return stroke should have the deflection shown in Fig.6.

5. Experimental Part

A generator of the type described

was constructed in the laboratory of the MEIS television authority. Toroidal
100 ferrocart 2000 II (Bibl.4) was used for the cores of the transformers. The inside diameter is 8 mm; the outside diameter, 18 mm; and the thickness, 5 mm.

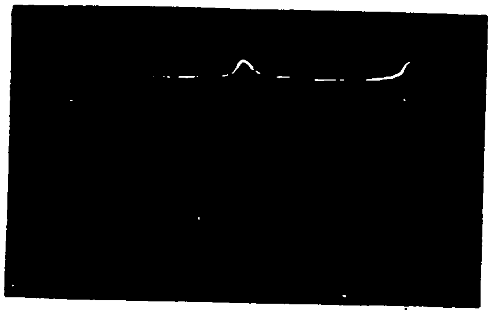

Fig.7

The generator contains 12 cores. The primary winding of the transformers is divided into two parts of 74 windings each and is inserted in the plate circuit of a push-pull amplifier; this permits compensation for the direct plate current. The amplitude of the sawtooth current is 24 ma. At the secondary windings of the transformers (w_2 = 500 turns), pulses of 2.5 v are obtained (Fig.7).

During the return stroke and at the beginning of the direct stroke, undesirable voltage surges take place as a result of a current jump in the primary winding. For this reason, we insert a block in front of the filter; this block permits cutting out all undesirable surges of the voltage curve to the accumulator output, and to replace them with Pi-pulses, the amounts of which may be regulated.

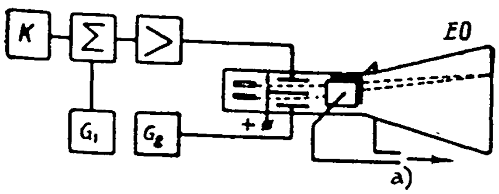

Fig.8

a) To horizontal scanning

Such a pulse plays an essential role, since it forms the generator output voltage not during the return stroke of the sawtooth current, which coincides with the return stroke of the beam of the electron-radial tube, but a little later, due to the delay in passing through the filter.

The generator has been used to superimpose two simple rasters (Fig.10). The block diagram of the experimental setup is shown in Fig.8, where K is a generator with controlled voltage form, $G_{1,2}$ are generators of sawtooth voltage, and EO is a double-beam oscillograph.

Fig.9

Fig.10

The voltage from the generator G_1 was directed toward the input of the vertical amplifier of the first beam, and the voltage from generator G_2 toward the amplifier of the second beam. One of the beams was modulated in brightness. Since the voltage forms of the generators G_1 and G_2 differed, two rasters, different from each other, showed on the screen of the instrument EO when the generator K was switched off (Fig.9).

As is evident from the drawing, the maximum deviation of the lines which were modulated in brightness from the corresponding lines of the second raster is approximately 0.66 of the distance between two lines of this second raster. The scanning inaccuracy is thus equal to

$$\varepsilon = \frac{\Delta}{h} 100\% =$$

$$= \frac{0,66}{9} 100 = 7,3\%$$

By selecting a suitable voltage form of the generator K, the scanning inaccuracy was reduced approximately 25 times, i.e., was reduced to a value of the order of 0.3% (Fig.10).

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To obtain a more accurate combination of rasters we must also regulate the form of the lines (and not only their position), since the deflecting systems of the two beams set up different geometric raster distortions.

The results of this experiment permit the conclusion that, by using this method, we can set up generators whose inaccuracy satisfies the operating conditions of electron-radial re-recording tubes.

In conclusion, the author expresses his appreciation to Prof.S.I.Katayev for valuable advice on the problems touched in this article.

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ON SPIRAL TELEVISION SCANNING

by

L. D. Fel'dman and

M. Z. Yudich

The author states the operating principles, advantages, and shortcomings of different types of spiral scanning. Some of them have found application in the industrial television equipment of the French firm "Laboratoires Derveaux". Two types of scanning are proposed for the first time.

1. Statement of the Problem

We must set up a type of scanning which permits clear reproduction of the central part of an image. When the scanning is of this type, despite the fact that the peripheral parts are less clear, the image is taken as being sufficiently clear, and the frequency band may be reduced considerably.

2. Solution

Since the image should be clear in the center, then, naturally, we must attain a state where the beam moves more slowly in the central part than it does in the periphery, and where the law for the change of speed in the movement of the beam from the center to the edge satisfies the condition of maximum reduction of the band. If the beam follows a path, for example, according to an Archimedean spiral, then the required conditions are satisfied. Actually, if each of the spiral turns (it may with sufficient accuracy be considered a closed circle) is formed in one period of the deflecting current - a period which is the same as the time it takes to form the other turns - then the circumferential velocity of the movement of the electronic spot on turns near the center will be less than on peripheral turns.

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To form a spiral on the screen of a television tube we must supply the deflecting system with two sinusoids with a 90° phase shift and 100% modulation of some function (depending upon the purpose).

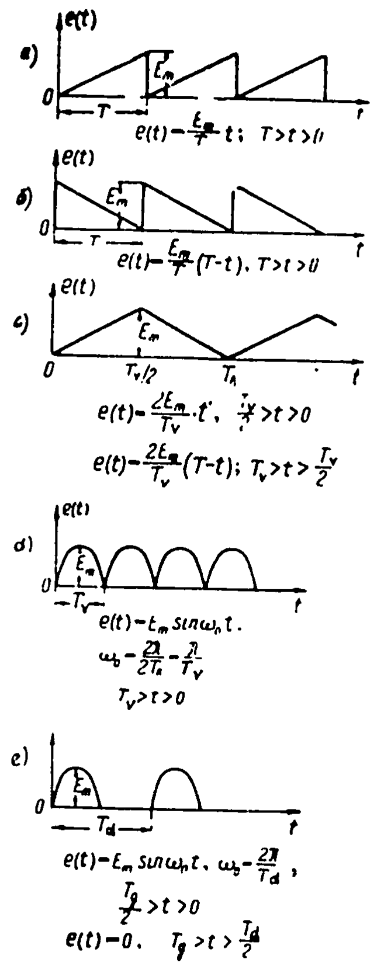

Fig.1

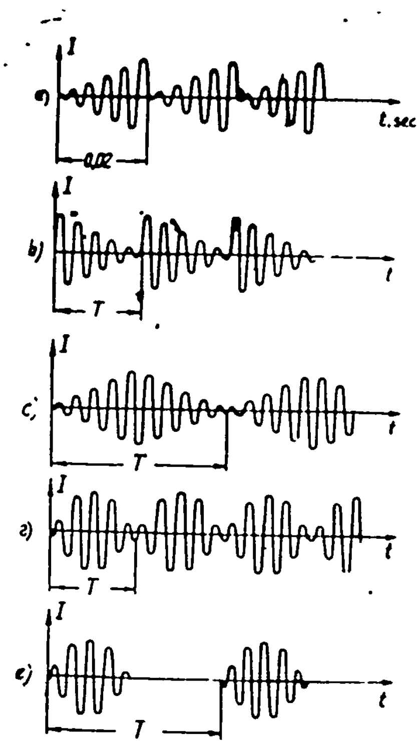

Fig.2

In the types of scanning proposed below a sinusoid of 17.15 kc is used. This number was chosen by taking into account the division 7 : 7 : 7, and from considerations of assuring maximum clarity, since the number of turns at the 50-cycle "frame" frequency is equal to $\frac{17\,150}{50} = 343$, i.e., 686 "lines". The modulating is done with functions of the types shown in Fig.1.

Diagrams of the sinusoids modulated by these functions are shown in Fig.2.

Let us examine each of the deflecting currents.

a) The current is formed by modulating a 17.15 kc sinusoid with a 50-cycle sawtooth current. When it is fed to the deflecting coil of the tube in the other coil, which is inductively coupled with this one, the same current is induced, with a 90° phase shift, an Archimedean spiral is obtained. In the central portion, the beam moves with a smaller peripheral velocity, and for this reason luminescence in the center is more intense than at the edges. Experimentally, the dependence

$$I = \frac{C}{\sqrt{D}}.$$

is established; I is the intensity of luminescence, C is some constant, and D is the diameter of any turn of the spiral. The dependence is not valid for the center of the screen (D = 0), where I has a finite value, nor for large values of D, when I = 0.

The evident unevenness in luminescence is easily compensated for with special correction pulses (Fig.3) which must be supplied to the brightness electrode. Here the law for change of correction voltage is similar to that described above.

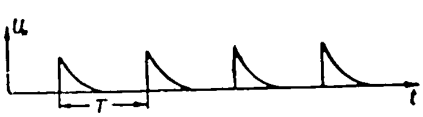

Fig.3

It is best to mix these pulses in the signal of the transmitter, transmitting the signal in reduced form near the center, and in increased form near the edge. In this case brightness correction at the receiving end is done automatically.

Let us deduct the formula for the "variable" frequency band, which is necessary for obtaining maximum clarity on a given turn of the spiral. On the basis of what has been stated above, we will require that the image be clear in the central portion. A gain will then be obtained in the band as a result of the properties

Let us assume that the image is maximally saturated, i.e., light and dark "cells" follow along the length of a turn (Fig.4).

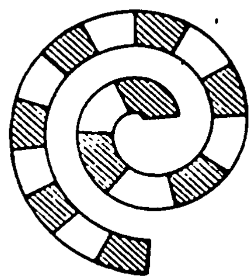

Fig.4

Actually, allowing for a small error, the truncated segments may be considered squares whose sides are equal to the diameter of the tube's spot.

We can show that the signal of such an image changes according to the law

$$y = \frac{\pi d^2}{4} \; y_1 - (2y_1 - y_2) \frac{d^2}{8} (\alpha - \sin \alpha),$$

where y is the amount of the signal, y_1 is the white cell signal, y_2 is the dark cell signal, α is the angle according to Fig.5, and d is the diameter of the spot.

The graphically illustrated signal y differs very little from a sinusoid. For this reason a signal released in such an image may be considered as one which changes according to the harmonic law.

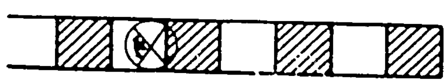

Fig.5

Let us count up the number of cells up to any turn (the "current" turn). Evidently, if we consider a turn a circle, on the x^{th} turn, at a radius on which x turns have been placed, we will obtain

$$n = 2 \pi x,$$

where x is the (current) number of a turn, and n is the number of cells in a turn.

The overall number of cells

$$N = \int 2\pi \; x dx = \frac{2\pi x^2}{2} = \pi x^2;$$

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The number of periods is equal to $\frac{1}{2}\pi x^2$; and finally

$$f_v = \frac{\pi x^2}{2} m,$$

where f_v is the highest frequency in the spectrum, and m is the number of frames in 1 sec.

Taking into account the fact that excessive clarity in a turn (let us call it "tangential" clarity) only increases the band without increasing the clarity, since the latter is limited by the "radial" clarity (i.e., the clarity along the raster's radius) just as in line-frame scanning, let us interpolate the coefficient 0.75.

Then when we substitute m = 50

$$f_v \approx \Delta f = \frac{\pi x^2}{2} 50 \cdot 0{,}75 = 60\ x^2$$

Limiting the maximum clarity by the 200th turn (see above), we will obtain a band of

$$\Delta f = 2{,}4\ \text{mc}$$

Let us note that f_{min} = 50 cycles, since the elemental transmitted image is a black circle with a radius which is equal to one half the radius of the tube.

b) Practically speaking, scanning of this type differs in no way from type a. In this case the beam begins its movement from the edge to the center and then returns to the center again.

From a purely physical point of view, the "spectrum density" (i.e., the number of harmonics on a definite portion of the frequency axis) depends upon the "time losses"

$$H = \frac{T - t}{-}.$$

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where θ is the time losses, T is the sequence of the pulses, and τ is the duration of a pulse.

In the case of spiral scanning, a considerable gain in time is obtained. In this case the time losses go down as far as 2% of the overall transmission time for scanning of types a and b, - instead of 26 - 30% for the usual type of scanning. Reducing the time losses permits us to transmit the same energy with a smaller frequency band.

c) This type of scanning is interesting in that "time losses" are in general absent. The beam begins its movement from the center in a spiral, goes to the edge of the tube, and then returns in a spiral to the center. The spectrum of this type of scanning is more narrow than in scanning of type a and b.

d) In modulating the 17.15 kc sinusoid of a positive half-wave sinusoid, the visible raster on the screen is corrected in brightness, since spacing of the turns (reduction of brightness in the center) corresponds to the beginning of the half-wave (the derivative attains a maximum) and densification of the turns (increase in brightness on the periphery) corresponds to the maximum of the half-wave (the derivative reverts to zero). The time losses in this case are also equal to zero.

e) The advantages of type d scanning are retained here, with the exception of the fact that there are considerable time losses (50%), which lead to the widening of the frequency band. This type of scanning may be obtained by supplying one of the tube's grids with sinusoids of 17.15 kc and 50 cycles.

3. Experiment

Types a, d, and e scanning have been obtained experimentally in the laboratory. The experimental installations are presented in the form of block schemes in Figs.6, 7, and 8.

In Fig.6 we have presented a block diagram of the system for obtaining spiral scanning in which the sinusoidal oscillation of a frequency of 17.15 kc is modulated with sawtooth oscillation. In the diagram, BG is a blocking generator, RK is

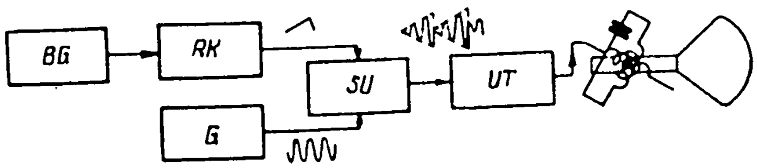

Fig.6

the discharge cascade, G is a generator of 17.15 kc, SU is a frequency-changer amplifier, and UT is a current amplifier. Here the modulator is the discharge cascade, which forms a saw and is commutated by the blocking generator. The modulation is accomplished by supplying the plate and screen grid of the tube with high voltage which varies according to the sawtooth law. The grid of this same tube is furnished with sinusoidal voltage of 17.15 kc. Then the modulated sinusoid is amplified, shifts 90° in phase, and sets up a deflecting current.

The block diagram presented in Fig.7 (where M is the modulator) is used for obtaining spiral scanning with brightness correction. The sinusoidal voltage of

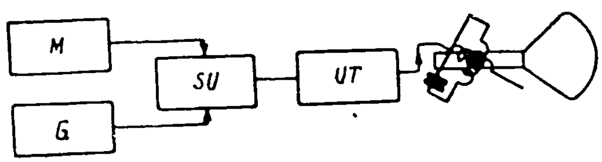

Fig.7

17.15 kc is here modulated by the double half-period rectified voltage of the network. This is done in view of the fact that, for current feed to the plates of the frequency-changer cascade and the amplifier (to increase the modulation depth) we use unfiltered high voltage from the usual double half-period rectifier. The functions of the other cascades are analogous.

Type e scanning may be done on the basis of the block diagram of Fig.8; here an ordinary transformer is used as modulator. The voltage of the network is supplied to the same grid as the 17.15 kc sinusoidal voltage. The essential shortcoming of type e scanning in comparison with type d scanning is the fact that it re-

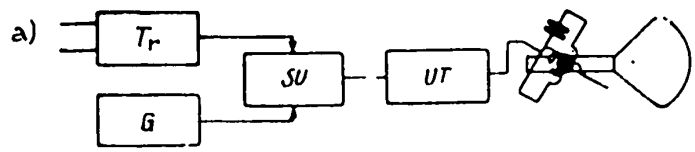

Fig.8

a) Mains, 50 cycles

quires broadening of the band.

4. Conclusions

Experimental and theoretical investigations permit the conclusion that spiral scanning will find application in industrial television equipment.

Let us point out specific new applications of this type of scanning.

1. Transmission of an image from revolving objects. If an image from a revolving object is transmitted and in the receiving apparatus the rotor of the phase inverter is made to revolve with the same angular velocity in the opposite direction, the image on the screen will be stationary. This will permit use of the system in rockets and inter-planetary vessels.

2. Speed Measurement. In radio communication between two objects, one of which is moving at a sufficiently high speed (for example, a rocket), when a scanning signal is included in the transmission of this object, a change is observed in the sawtooth filling frequency; this phenomenon is due to the Doppler effect. This change corresponds to a turning of the image at the point of reception. The speed of the moving object may be judged from the angle of rotation.

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CHARACTERISTICS OF THE APERTURE EFFECT IN TELEVISION

by

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In this article, the author presents a review of many papers pertaining to the characteristics of the aperture effect in television. He establishes the basic characteristic, "the law of distribution of a single luminous flux". All the other characteristics (frequency, pulse, transitional characteristics) are expressed as functions of the law of distribution. The author points out the possibilities of measuring the parameters of the scanning element by the pulse characteristics obtained as a result of experiments.

The conclusions drawn in this article may be applied not only to television systems but also to other electro-optic systems (phototelegraphy, sound recording).

1. Introduction

By the aperture effect in television we mean distortions linked with the finiteness in the dimensions of a television system's scanning elements. The aperture effect shows up in a reduction of the resolving power (the clarity and the sharpness of the images) of television systems, not only in the direction of the line scanning*, but in a direction perpendicular to the line scanning as well.

A study of the resolving power of transmitting and receiving television

*We assume that the scanning is done along horizontal lines with equal displacement of the scanning element in a vertical direction to an extent equal to the scanning pace during the movement along the lines.

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apparatuses boils down in essence to a study of the appearance of the aperture effect in them. The mere consideration of the particular characteristics of the elements of the television channel (including objectives, transmitting tubes, amplifiers, receiving devices) - and such consideration is necessary for the design and constructing the systems - requires in turn the presence of uniform characteristics which describe processes which show up the same on the screen of the television receiver.

In the scanning method used at present there is a simple connection between the linear dimensions of parts in the scanning field and the time of the corresponding process of changing the photoelectric current (and therefore of changing the control voltage at the input of the final receiving apparatus) through the invariable speed of motion of the scanning element. Thanks to this connection, concepts such as "the frequency characteristic of the scanning aperture" or "the effective diameter of the electric communication channel" take on meaning.

In a study of the individual elements of the television tract, some specific method of study is usually given preference. So, in studying or planning electric circuits we establish the frequency or the transitional characteristic; in studying receiving tubes we measure the diameter and distribution of brightness on a section of a stationary spot focused on the screen; in studying the transmitting tubes or the entire tract as a whole, we use line tables made up of black and white bands (the electric analogy is rectangular pulses, Bibl.3).

In published works dealing with the aperture effect, etc. (Bibl.1,2), the frequency characteristics method is usually preferred in study by the line table method; analytical expressions connecting the system parameters and the form of the characteristics are not made (Bibl.5). The absence of a single system of connected characteristics makes it difficult to consider the effect of all the elements conjointly or to evaluate the effect of an individual element upon the resultant characteristic.

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Here below we present a generalized system of the characteristics of the aperture effect and set up the connection between them.

2. Physical Characteristics. The Law of Distribution

The concept of "the scanning aperture" (or diaphragm) as applied to actual television equipment is provisory in character. However, in every concrete case we may speak of a certain hypothetical diaphragm which is equivalent in its action to the action of a real aperture. For example, in receiving tubes the finite dimensions of a cross section of the electronic beam, together with the light diffusion on the screen and in the retort, lead to a state in which the luminous point possesses a measurable area and is characterized by a specific distribution of brightness on the section.

With reference to transmitting apparatuses we may also, in every case, speak of the real picture's similarity to the action of some hypothetical aperture; here the analogy should take into account all the factors which really have an effect (the density distribution of electrons in the section of the scanning beam, the effect of the electric and magnetic fields, the effect of the spreading of charges, the diffusion of electrons, and the like).

Let us introduce the concept of the "law of distribution of a single luminous flux". As applied to the transmitter, this law expresses the change in the amount of the luminous flux allowed to pass through the diaphragm (and therefore in the amount of the photoelectric current as well, since we assume a directly proportional dependence between them) when the scanning of the luminous object is in the form of a very narrow bright band on a black background which is perpendicular to the direction of the supposed movement of the diaphragm, and with the condition that the resultant luminous flux admitted through the diaphragm is equal to a unit. As applied to receiving equipment, this law expresses the character of the change in the elemental luminous flux admitted by a very narrow slot when the spot focused o-the screen moves evenly in a direction perpendicular to the slot, with the condition that the resultant luminous flux admitted through the slot is equal to a unit.

The law of distribution of a single luminous flux is analogous to the law of change in the output signal of a quadripole when its entrance is acted upon by a signal in the form of a δ-function (a single pulse).

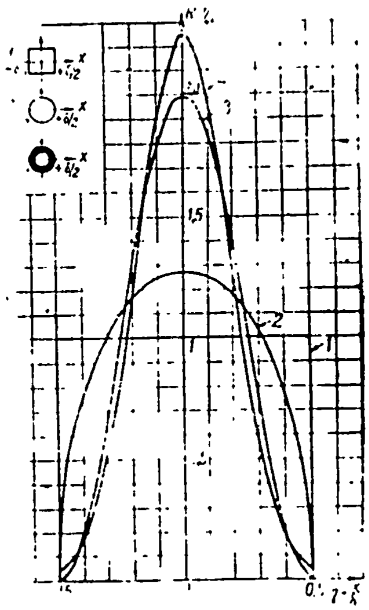

Fig.1

Let us suppose that the diaphragm of the transmitter is uniformly transparent or that the intensity of illumination of the surface, covered by the spot, on the screen of the receiving tube is the same in any point of the section*. The diaphragm is orientated with respect to the coordinate system xoy which moves jointly with the diaphragm along the axis x, and intersects the slot or the narrow luminous object. If the width of the object is dx, then the elementary luminous flux admitted by the diaphragm when the object coincides with the point x will be equal to

$$dF = Ky(x)dx.$$

The constant K is determined from the condition that the integral luminous flux equals unity

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*Further on, we will speak only of the aperture effect of the transmitter. If one desires, one may make the analogy with the receiver, keeping in mind the proportional relationship between the apparent brightness and the exposure (the product the intensity of illumination and the time) on a given point of the screen.

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$$\int_S dF = K \int_{-\infty}^{\infty} y(x)\,dx = 1,$$

whence $K = \frac{1}{S}$, where S is the area of the diaphragm. In this case, the law of distribution of a single luminous flux is defined in the form

$$R(x) = \frac{dF}{dx} = \frac{1}{S}\,y(x). \qquad \text{(1a)}$$

i.e., is defined by the configuration of the diaphragm y(x).

When the diaphragm is not uniformly transparent, it may be likened to a certain size with a base which corresponds in plane xoy to the diaphragm configuration, and with a height z which is proportional to the transparency of a given point (x, y). Then, the elemental luminous flux may be expressed as

$$dF = \frac{1}{V}\left[\int_{-\infty}^{\infty} z(x, y)\,dy\right]dx.$$

Then the law of distribution will be

$$R(x) = \frac{1}{V}\int_{-\infty}^{\infty} z(x, y)\,dy, \qquad \text{(1b)}$$

where V is the size of the space model of the diaphragm*.

Let us look over some examples.

1. A uniformly transparent square aperture with side s (Fig.1, curve 1)

$$\left.\begin{aligned} R(\eta_1) &= 1 \qquad -\frac{1}{2} < \eta_1 < \frac{1}{2} \\ R(\eta_1) &= 0 \qquad -\frac{1}{2} \geq \eta_1 \geq \frac{1}{2} \end{aligned}\right| \qquad \text{(2a)}$$

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*The function defined by expression (1b) differs from the function R, introduced by Ya.A.Ryftin [see eq.(2) in Bibl.3], only in that it has been standardized.

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where $n = \frac{x}{\delta}$

2. A round, uniformly transparent diaphragm with a diameter of δ (Fig.1, curve 2)

$$\left.\begin{array}{ll} R(\eta) = \frac{4}{\pi}\sqrt{1-4\eta^2} & -\frac{1}{2} < \eta < \frac{1}{2} \\ R(\eta) = 0 & -\frac{1}{2} \geqslant \eta \geqslant \frac{1}{2} \end{array}\right\}. \qquad (2b)$$

3. A round diaphragm which has a diameter of δ and a transparency which is near to the real distribution of electrons in the beam, is characterized by a quadratic-cosine law of distribution (Fig.1, curve 3)

$$R(\eta) = 2\cos^2\pi\eta = 1 + \cos 2\pi\eta \quad \left.\begin{array}{l} -\frac{1}{2} < \eta < \frac{1}{2} \\ -\frac{1}{2} \geqslant \eta \geqslant \frac{1}{2} \end{array}\right\}. \qquad (2c)$$

As was shown in Bibl.4, in a diaphragm with such a law of distribution the transparency along the radius is approximately described by the equation

$$\frac{z}{z_0} = 0{,}675\,(1-4r^2)^{\frac{3}{2}} + 0{,}325\,(1-4r^2)^{\frac{7}{2}},$$

where z is the transparency of a point located at a distance of r from the center;

z_0 is the transparency in the center;

r is the distance along the radius relative to the diameter δ.

4. Another diaphragm, close to those encountered in practice, is characterized by a "probability" law of distribution

$$R(\eta) = \frac{4}{\sqrt{\pi}}\, e^{-(4\eta)^2} \qquad (2d)$$

In contrast to the other diaphragms, this one, which is a figure of axial symmetry, is not characterized by a sharply traced contour, and when $x = \frac{\delta}{2}$ we will

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obtain R(0.5) = 0.041. This law of distribution in some measure takes into account the effect of the diffused electrons of the beam. Since $\frac{R(0.5)}{R(0)} = 0.018$, we may consider that δ is approximately the diameter of this diaphragm.

For asymmetrical diaphragms the laws of distribution are more complex functions of η; here the law of distribution depends upon the orientation of the diaphragm in reference to the coordinate system xoy.

From a comparison of the curves of Fig.1 it follows that the diaphragms with quadratic-cosine and probability laws of distribution are more effective from the point of view of correct reproduction of an experimental object than uniformly transparent diaphragms of the same dimensions are.

With the help of the law of distribution we may establish the character of the change in the luminous flux during scanning of an object with any change in intensity of illumination E(x). The resultant luminous flux, admitted by the moving diaphragm at a certain moment of time, may be presented in the form of a sum of elemental luminous fluxes. In this moment of time let the beginning of the coordinate system xoy, which is fixed in reference to the diaphragm, coincide with some point x' of the object. Then, if the whole surface of the diaphragm is divided into separate portions which have a width of x and within whose limits the intensity of illumination may be considered invariable, then the n^{th} elementary luminous flux may be expressed as

$$\Delta F_n = KE(x' + n\,\Delta x)\,R(n\,\Delta x)\,\Delta x. \qquad [n = \pm(1, 2, 3 \ldots)]$$

When we sum up all the elemental luminous fluxes within the limits of the contours of the diaphragm, after transition to the limit correlations we will obtain

$$F(x') = K\int_{-\infty}^{\infty} E(x' + x)\,R(x)\,dx, \qquad (3)$$

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where K is a constant factor, numerically equal to the area of the diaphragm (if the latter is uniformly transparent), or to the size of the space model of the diaphragm. In practice, the limits of integration are the confines within which R(x) has finite values, i.e., $\pm \frac{\delta}{2}$, if the beginning of the coordinate system xoy coincides with the center of the diaphragm.

3. The Coefficient of Transmission of an Harmonic Signal

The coefficient of transmission Y characterizes the neutralizing effect of the diaphragm on the process of transforming the luminous object, whose intensity of illumination changes according to the harmonic law, into a photocurrent (luminous flux). This coefficient is the frequency characteristic of the moving diaphragm and is defined as the relationship between the amplitude of the harmonic component of a luminous flux with a given frequency and the amplitude of the harmonic component of a luminous flux with "zero" frequency.

Let the luminous object be characterized by the harmonic change in intensity of illumination in the direction of the diaphragm's motion.

$$E(x') = A\left(1 \cdot \cos 2\pi \frac{m}{2a} x'\right),$$

where $\lambda = \frac{2a}{m}$ is the length of a wave of the m^{th} harmonic component, and 2a is the length of a wave of the first harmonic (for example, the length of a line). We will examine only the variable component which interests us, i.e., we will reckon the light values from the mean level and then

$$E(x') = A \cos \pi \frac{m}{a} x'$$

In accordance with formula (3) the luminous flux admitted by the moving diaphragm (and therefore the photo-current as well) is defined by the expression

$$F_m(x') = AK \int_{-\infty}^{\infty} R(x) \cos \pi \frac{m}{a} (x + x')\, dx =$$

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$$= AK\left[\int_{-\infty}^{\infty} R(x)\cos\pi\frac{m}{a}x\,dx\right]\cos\pi\frac{m}{a}x'.$$

If the frequency is equal to zero, i.e., m = 0, then

$$F_0(x') = AK\int_{-\infty}^{\infty} R(x)\,dx = AK.$$

By definition the relationship between the amplitudes is the coefficient of transmission. Let us again introduce the relative variable $\eta = \frac{x}{\delta}$, and also the relative frequency

$$\omega = 2\pi\frac{m}{2a}\delta = 2\pi\frac{\delta}{l} = 2\pi\frac{m}{M}, \qquad (4)$$

where $M = \frac{2a}{\delta}$ is the number of the diaphragm's diameters placed along a period of the first harmonic (for example, along a line). Then the coefficient of transmission of the harmonic signal will be written in the form

$$Y(\omega) = \int_{-\infty}^{\infty} R(\eta)\cos\omega\eta\,d\eta. \qquad (5)$$

Equation (5) testifies to the fact that the real functions $R(\eta)$ and $Y(\omega)$ are conjugate according to Fourier, i.e., the equation

$$R(\eta) = \frac{1}{\pi}\int_{0}^{\infty} Y(\omega)\cos\omega\eta\,d\omega. \qquad (6)$$

takes place.

Consequently from either of these two functions, which were established analytically, we may determine the other.

Calculating the frequency characteristics of the diaphragms examined above,

10 with the help of expression (5) we will obtain

1) for the square diaphragm (Fig.2, curve 1)

$$Y(\omega) = \frac{\sin\frac{\omega}{2}}{\frac{\omega}{2}}; \qquad (7a)$$

2) for the round, uniformly transparent diaphragm (Fig.2, curve 2)

$$Y(\omega) = 2\frac{J_1\left(\frac{\omega}{2}\right)}{\frac{\omega}{2}}, \qquad (7b)$$

where J_1 is a Bessel function of the first order;

3) for the round, square-cosine diaphragm (Fig.2, curve 3)

$$Y(\omega) = \frac{\sin\frac{\omega}{2}}{\frac{\omega}{2}\left[1-\left(\frac{\omega}{2\pi}\right)^2\right]}, \qquad (7c)$$

4) for the diaphragm with the probability law of distribution (Fig.2, curve 4)

$$Y(\omega) = e^{-\left(\frac{\omega}{8}\right)^2}. \qquad (7d)$$

These curves are only envelope spectral lines, since the frequencies receive only discrete values which are multiples of the fundamental frequency $\frac{\pi}{a}$.

Negative values received by the frequency characteristics of sharply outlined diaphragms at certain values of ω must be physically explained as follows: as the period of the m^{th} harmonic component along the diaphragm diameter is reduced, such a number of half-periods of oscillation is built up that the neutralizing luminous flux may become less than the mean (constant) value of the luminous flux which was taken at the beginning of the computing.

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By multiplying the ordinates of the frequency characteristics of different links we may obtain the resultant characteristics of the whole tract. However,

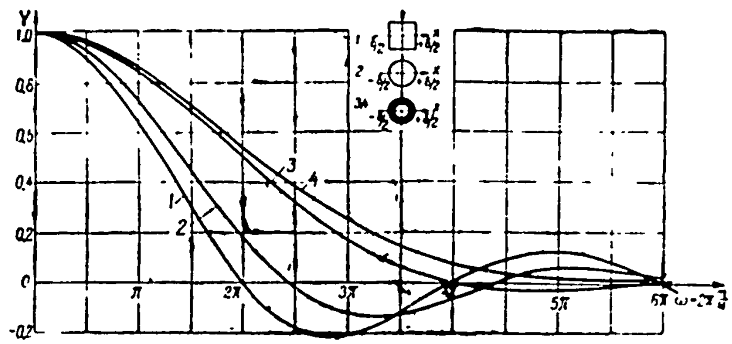

Fig.2

measuring these characteristics is inconvenient, since producing luminous objects with harmonic change in intensity of illumination is very difficult.

4. The Coefficient of Transmission of a Rectangular Signal

In practice, in television, wide use has been made of the method of evaluating the resolving power - in particular, the method of evaluating aperture distortions - in which a luminous object of alternating black and white bands is used as the testing object. This sort of object is often made in the form of converging wedge-shaped bands (Fig.3a), and the installation for testing the various links is made in such a way that, if desired, the scanning may be done along one selected line for which m is the characteristic number of pairs of bands which fit on one unit of length (or, recounting, on the length of a line). In analysis of the aperture effect, the readings of the registering instrument (an oscillograph or pointer gage) depend upon the number m (Fig.3b and 3c).

By the coefficient of transmission of a rectangular signal (Y_p) we mean the dependence of the amount of the maximum values attained by the luminous flux which is admitted through the diaphragm (and therefore by the photo-current or the voltage) upon the number of pairs of black and white bands - this dependence as related

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to the amount of the luminous flux when m is such that the aperture effect may be disregarded.

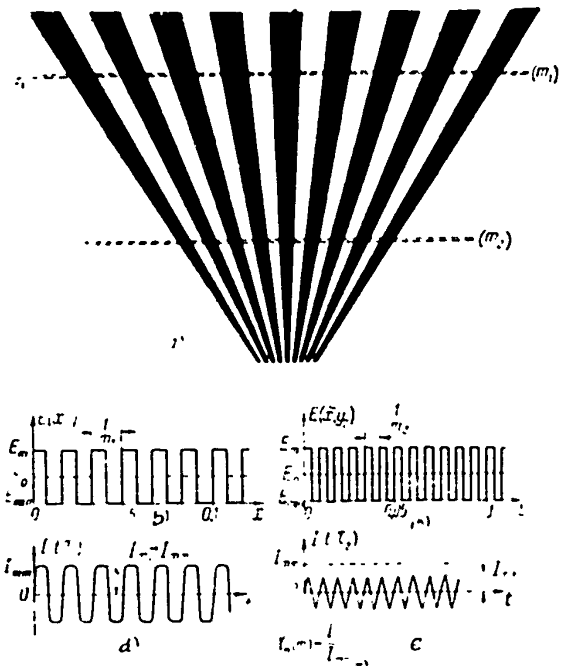

Fig.3

In Fig.3b and c we have shown the curves of change in intensity of illumination along lines y_1 and y_2 of the object which gives off a rectangular-form signal (Fig.3a) and in Fig.3d and e we have shown the corresponding changes in the photo-current. Then, by definition, $Y_p = \frac{J_{sh}}{J_{mm}} = f(m)$, where J_m is the maximum value attained by the photo-current at a given value of m, for example, at m_2, and J_{mm} is the greatest possible value of the photo-current at the smallest values of m, i.e., when the aperture effect may be disregarded.

Let us establish the connection between Y_p and the characteristics Y and R.

To do this we will assume that the law of change in intensity of illumination in the direction of the diaphragm's movement is expressed by the symmetrical rectangular curve $E(x') = E(-x')$. This function may be presented in the Fourier series

$$E(x') = \frac{4}{\pi} A \sum_{\kappa=1}^{\infty} (-1)^{\kappa+1} \frac{1}{2\kappa-1} \cos(2\kappa-1)\pi \frac{m}{a} x',$$

where A is the maximum value of the intensity of illumination (we are not interested in the constant component), and $m = \frac{2a}{\lambda}$ characterizes the structure of a field, i.e., indicates the number of pairs of black and white bands (the width of a band is equal to $\frac{\lambda}{2}$) placed along the measurement 2a (a line).

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After such an object has been scanned by a diaphragm with a diameter of δ, the amplitude of the first harmonic will have been changed $Y(\frac{m}{M})$ times, and the amplitude of the $(2k - 1)^{th}$ harmonic will have been changed $Y[(2k - 1)\frac{m}{M}]$ times, and $\frac{m}{M} = \frac{\omega}{2\pi}$; we drop the factor 2π for the sake of simplicity. Then according to (3) and (5) we have

$$F(x') = \frac{4}{\pi} AK \sum_{\kappa=1}^{\infty} (-1)^{\kappa+1} \frac{Y\left[(2\kappa - 1)\frac{m}{M}\right]}{2\kappa - 1} \cos(2\kappa - 1)\pi\frac{m}{a}x'.$$

To obtain Y_p we must determine the maximum values of the function $[F(x')]_{max}$. Evidently, the maximum values will correspond to the equation

$$\cos(2\kappa - 1)\pi\frac{m}{a}x' = 1$$

and

$$[F(x')]_{max} = \frac{4}{\pi} AK \sum_{\kappa=1}^{\infty} (-1)^{\kappa+1} \frac{Y\left[(2\kappa - 1)\frac{m}{M}\right]}{2\kappa - 1}.$$

We will obtain the coefficient Y_p if we relate $F(x')_{max}$ to the amount of $[F(x')]_{max}$ as $m \to 0$; this amount will equal AK Y (0) = AK.

Then we will obtain

$$Y_p = \frac{4}{\pi} \sum_{\kappa=1}^{\infty} (-1)^{\kappa+1} \frac{Y\left[(2\kappa - 1)\frac{m}{M}\right]}{2\kappa - 1}. \qquad (8)$$

Expression (8) establishes the connection between Y_p and Y. The briefer expression of Y_p as a function of the frequency is also interesting. This sort of dependence may be obtained by using eq.(5) and substituting Y, which is defined by this expression, in eq.(8). The result will remain the same if the order of integration and summation is changed

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$$Y_p = \frac{4}{\pi} \int_{-\infty}^{\infty} R(\eta) \left[\sum_{\kappa=1}^{\infty} (-1)^{\kappa+1} \frac{\cos(2\kappa-1)\omega\eta}{2\kappa-1} \right] d\eta. \tag{9}$$

When $-\frac{\pi}{2} < \omega\eta < \frac{\pi}{2}$, the series enclosed in brackets approaches $\frac{\pi}{4}$. For this reason

$$Y_p = \int_{-\infty}^{\infty} R(\eta)\, d\eta = 1; \quad -\frac{\pi}{2} < 2\pi\eta \frac{m}{M} < \frac{\pi}{2}.$$

Since η for sharply traced diaphragms cannot exceed $\pm\frac{1}{2}$, then even if we give η the limit values we may assert that for sharply traced diaphragms

$$Y_p\left(\frac{m}{M}\right) = 1; \qquad 0 < \frac{m}{M} < \frac{1}{2}. \tag{10a}$$

This last conclusion is understandable from physical considerations as well. Until the width of a black or white band is greater than (or equal to) the diameter of the diaphragm, the luminous flux manages to attain its maximum possible value when the diaphragm is moving.

When $\frac{m}{M} > 0.5$ we may also obtain simple analytical expressions for Y_p, if we note the following considerations. Let us rewrite expression (9) for a case where the diaphragms are symmetrical in reference to the vertical axis $[R(\eta) = R(-\eta)]$ and are limited by an interval of $-\frac{1}{2} < \eta < \frac{1}{2}$. Then we will obtain

$$Y_p = 2\int_{0}^{\frac{1}{2}} R(\eta) \left[\frac{4}{\pi} \sum_{\kappa=1}^{\infty} (-1)^{\kappa+1} \frac{\cos(2\kappa-1)\omega\eta}{2\kappa-1} \right] d\eta.$$

The series in brackets in the last expression approaches -1 when $\frac{\pi}{2} < \omega\eta < \frac{3\pi}{2}$; further, it approaches $+1$ when $\frac{3\pi}{2} < \omega\eta < \frac{5\pi}{2}$ and in general the sum is equal to $(-1)^k$ when $(k - \frac{1}{2})\pi < \omega\eta < (k + \frac{1}{2})\pi$, $(k = 1, 2, 3 \ldots)$.

Thus at every integration interval from $\eta = 0$ to $\eta = \frac{1}{2}$ the sub-integral function $R(\eta)$ takes on either positive or negative values depending on the amount of $\eta\omega$.

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So, from $\eta = 0$ to $\eta = \frac{\pi}{2\omega}$ the function is positive; from $\eta = \frac{\pi}{2\omega}$ to $\eta = \frac{3\pi}{3\omega}$ it is negative, etc. Thus if, for example, $\eta\omega$ lies in the interval of from $\frac{\pi}{2}$ to $\frac{3\pi}{2}$, then the integration interval may be split into two segments, and then

$$Y_P = 2\int_0^{\frac{\pi}{2\omega}} R(\eta)\,d\eta - 2\int_{\frac{\pi}{2\omega}}^{\frac{1}{2}} R(\eta)\,d\eta.$$

In general,

$$Y_P = 1; \qquad 0 < \frac{m}{M} < \frac{1}{2}. \tag{10a}$$

$$\frac{1}{2} Y_P = \int_0^{\frac{M}{4m}} - \int_{\frac{M}{4m}}^{\frac{1}{2}}; \qquad \frac{1}{2} < \frac{m}{M} < \frac{3}{2}; \tag{10b}$$

$$\frac{1}{2} Y_P = \int_0^{\frac{M}{4m}} - \int_{\frac{M}{4m}}^{\frac{3M}{4m}} + \int_{\frac{3M}{4m}}^{\frac{1}{2}}; \qquad \frac{3}{2} < \frac{m}{M} < \frac{5}{2}; \tag{10c}$$

$$\frac{1}{2} Y_P = \int_0^{\frac{M}{4m}} - \int_{\frac{M}{4m}}^{\frac{3M}{4m}} + \int_{\frac{3M}{4m}}^{\frac{5M}{4m}} - \int_{\frac{5M}{4m}}^{\frac{1}{2}}; \qquad \frac{5}{2} < \frac{m}{M} < \frac{7}{2} \tag{10d}$$

and so forth [the sub-integral function is everywhere $R(\eta)\,d\eta$].

For the diaphragms examined above we have:

1) the square diaphragm (Fig.4, curve 1) is

$$\begin{aligned} Y_P &= \frac{M}{m} - 1, \quad \frac{1}{2} < \frac{m}{M} < \frac{3}{2}; \\ Y_H &= 1 - 2\frac{M}{m}; \quad \frac{3}{2} < \frac{m}{M} < \frac{5}{2}; \\ Y_B &= 3\frac{M}{m} - 1, \quad \frac{5}{2} < \frac{m}{M} < \frac{7}{2}; \end{aligned} \tag{11a}$$

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2) the round transparent diaphragm (Fig.4, curve 2) is

$$Y_p = \frac{2}{\pi}\left[\frac{M}{2m}\sqrt{1-\left(\frac{M}{2m}\right)^2} + \arcsin\frac{M}{2m}\right] - \frac{1}{2}; \qquad \frac{1}{2} < \frac{m}{M} < \frac{3}{2}$$

$$Y_p = \frac{2}{\pi}\left\{\frac{M}{2m}\left[\sqrt{1-\left(\frac{M}{2m}\right)^2} - 3\sqrt{1-\left(\frac{3M}{2m}\right)^2}\right] + \arcsin\frac{M}{2m} - \arcsin\frac{3M}{2m}\right\} + \frac{1}{2}; \qquad \frac{3}{2} < \frac{m}{M} < \frac{5}{2}; \tag{11b}$$

3) the square-cosine diaphragm (Fig.4, curve 3) is

$$Y_p = \frac{M}{m} - 1 \quad \frac{2}{\pi}\sin\frac{\pi}{2}\frac{M}{m}; \qquad \frac{1}{2} < \frac{m}{M} < \frac{3}{2};$$

$$Y_p = 1 - 2\frac{M}{m} \quad \frac{2}{\pi}\left(\sin\frac{\pi}{2}\frac{M}{m} - \sin\frac{3\pi}{2}\frac{M}{m}\right); \qquad \frac{3}{2} < \frac{m}{M} < \frac{5}{2}. \tag{11c}$$

All these considerations also apply, in general, to diaphragms with a probability law of distribution. However, we must keep in mind the fact that when $\frac{m}{M}$ is changed from 0 to $\frac{1}{2}$ the value of Y_p changes from 1 to 0.995. For the remaining intervals (Fig.4, curve 4)

$$Y_p = 2\Phi\left(\frac{M}{m}\right) - \Phi(2); \qquad \frac{1}{2} < \frac{m}{M} < \frac{3}{2};$$

$$Y_p = 2\Phi\left(\frac{M}{m}\right) - 2\Phi\left(\frac{3M}{m}\right) \quad \Phi(2); \qquad \frac{3}{2} < \frac{m}{M} < \frac{5}{2}; \tag{11d}$$

where $\Phi(x) = \frac{2}{\sqrt{\pi}}\int_0^{\pi} e^{-z^2}\,dz$ is the "normal integral of probability" [$\Phi(2) = 0.995$].

Comparing the experimental and theoretical data in this method of investigation is a very effective means of determining the parameters of a diaphragm. Actually, as a result of experimental investigation we obtain the dependence of Y_p upon m, which is the absolute number of pairs of bands; we may with a sufficient degree of accuracy mark on the graph that value of m at which the curve begins to fall off sharply. This value of m, multiplied by 2, also gives us the value

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100 $M = \frac{2a}{\delta}$, i.e., the size of the diameter of the diaphragm. Comparing the character of the curve with the theoretical data when $\frac{m}{M} > \frac{1}{2}$ permits us to establish the law of distribution approximately. If we know the diameter and the law of distribution, we may express the frequency and transitional characteristics which are necessary for a study of the tract as a whole.

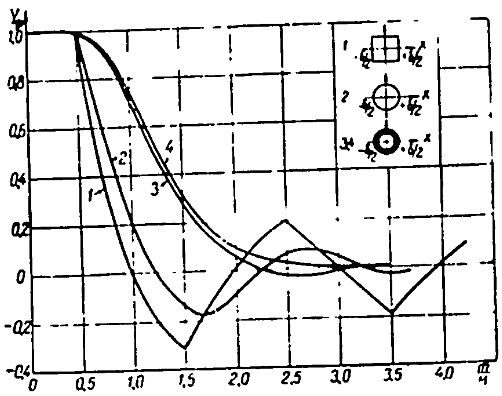

Fig.4

The coefficient of transmission of a rectangular signal gives an idea of the aperture effect which does not correspond to what we perceive when we examine a distorted image. Actually, when $\frac{m}{M} = 0$, as also when $\frac{m}{M} = \frac{1}{2}$ the values of the coefficient of transmission are the same. However, it is clear that when we examine an image whose brightness changes according to the rectangular law, what we perceive will be different from what we perceive when we examine an image which changes in brightness according to the triangular law, even though the maximum values in both cases may be the same. What we perceive may be more faithfully characterized by the active value of the corresponding curve.

The dependence of the operating values of the photo-current (the luminous flux) upon the frequency in scanning objects which change in intensity of illumination according to the rectangular law - this dependence will be referred to as the operating coefficient of transmission of a rectangular signal Y_{pd}. For experimental investigation of Y_{pd}, a gage which measures the operating values of alternating current is switched in at the exit of a special installation.

Let us establish the connection between Y_{pd} and the other characteristics. In deducing formula (8) we established that the luminous flux may be expressed by a trigonometric series with harmonic amplitudes which are in proportion to

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$Y[(2k-1)\frac{m}{M}]$. To obtain Y_{pd} it is sufficient to integrate the function $F(x')$ within the limits of from $x' = \frac{\lambda}{2}\frac{a}{2m}$ to $x' = -\frac{\lambda}{2} = -\frac{a}{2m}$, to divide the value we obtain by $\frac{\lambda}{2} = \frac{a}{m}$ and to refer the result to the greatest value of AK. Then we will obtain

$$Y_{pd} = \frac{4}{\pi}\frac{m}{a}\sum_{\kappa=1}^{\infty}(-1)^{\kappa+1}\frac{Y\left[(2\kappa-1)\frac{m}{M}\right]}{2\kappa-1}\int_{-\frac{a}{2m}}^{\frac{a}{2m}}\cos(2\kappa-1)\pi\frac{m}{a}x'dx'.$$

After simple reckoning and reformation, we will obtain

$$Y_{pd} = \frac{8}{\pi^2}\sum_{\kappa=1}^{\infty}\frac{Y\left[(2\kappa-1)\frac{m}{M}\right]}{(2\kappa-1)^2}. \qquad (12)$$

Using formula (5) (for symmetrical diaphragms), and making a series of reorganizations analogous to those made in deducting formulas (10), we will obtain

$$Y_{pd} = 1 - 8\frac{m}{M}\int_0^{\infty}R(\eta)\,\eta\,d\eta; \quad 0 < \frac{m}{M} < 1, \qquad (13a)$$

$$\frac{1}{2}Y_{pd} = \int_0^{\frac{M}{2m}}R(\eta)\left(1 - 4\frac{m}{M}\eta\right)d\eta - \int_{\frac{M}{2m}}^{\infty}R(\eta)\left(1 - 4\frac{m}{M}\eta\right)d\eta;$$

$$1 < \frac{m}{M} < 2 \qquad (13b)$$

and so forth. It is characteristic that in the interval of from 0 to $\frac{m}{M} = 1$ the function Y_{pd} decreases linearly, independently of the law of distribution. Graphs of the $Y_{pd}(\frac{m}{M})$ dependences for the diaphragms examined above are shown in Fig.5. If we know approximately the law of distribution of the "diaphragm" which is being investigated, then by comparing the experimentally taken curve of $Y_{pd}(m)$ with the theoretical dependences we may establish δ.

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5. The Transitional Characteristic

The transitional characteristic will refer to the dependence of the change in the luminous flux (the photoelectric current) upon the position of the diaphragm,

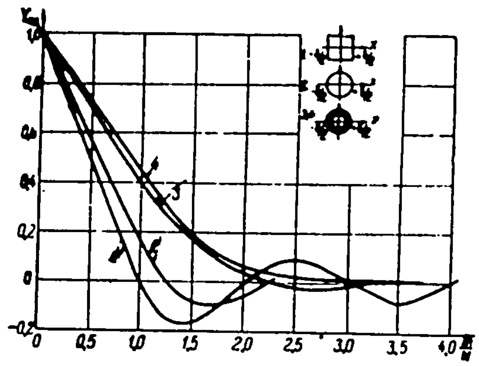

Fig.5

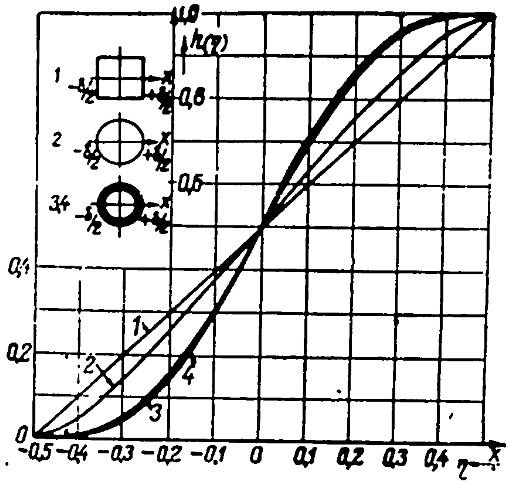

Fig.6

when we are scanning an object in the form of a sharp transition from a luminous field with one invariable intensity of illumination to a field with another invariable intensity of illumination. The transitional characteristic is likewise standardized in that the full change in the luminous flux is taken as equal to unity.

In this case, the transitional characteristic is defined by the expression

$$h(\eta) = \int_{-\infty}^{\eta} R(\eta)\, d\eta. \tag{14}$$

The transitional characteristics of the diaphragms we have examined may be expressed in the following form:

1) the square diaphragm (Fig.6, curve 1) is

$$h(\eta) = \frac{1}{2} + \eta; \tag{15a}$$

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2) the round transparent diaphragm (Fig.6, curve 2) is

$$h(\eta) = \frac{1}{2} + \frac{1}{\pi}(2\eta\sqrt{1-4\eta^2} + \arcsin 2\eta); \tag{15b}$$

3) the square-cosine diaphragm (Fig.6, curve 3) is

$$h(\eta) = \frac{1}{2} + \eta + \frac{1}{2\pi}\sin 2\pi\eta; \tag{15c}$$

4) the "probability" diaphragm (Fig.6, curve 4) is

$$h(\eta) = \frac{1}{2} + \frac{1}{2}\Phi(4\eta). \tag{15d}$$

Outside the interval $-\frac{1}{2} < \eta < \frac{1}{2}$, all transitional characteristics with the exception of the last one are equal to zero when $\eta \geq -\frac{1}{2}$ and equal to 1 when $\eta \geq \frac{1}{2}$.

An examination of the transitional characteristics shows that, although the zones of the transitional state are equal for sharply delineated diaphragms, the two latter diaphragms are more effective in that the slope of these characteristics is considerably greater in the area adjoining $\eta = 0$. The transitional process may be characterized by the effective diameter of the diaphragm, i.e., by the abscissa of the transitional characteristic which corresponds to the change of $h(\eta)$ from 0.1 to 0.9 of the established value. In this case $\delta_{0.1-0.9}$, for the diaphragms in question, is equal respectively to 0.8, 0.67, 0.5, and 0.47 of the diaphragm diameter δ. The effective diameter can be characterized by the maximum slope of the transitional characteristic of $h'(\gamma)_{max} = R(0)$. If we make an approximate representation of the transitional characteristics as being straight, with inclinations equal to the maximum values of the slope of a given transitional characteristic, then the values of the effective diameter will be equal, respectively, to 1, 0.78, 0.5, and 0.44 of the diaphragm diameter.

A study of the resultant transitional processes in the tract may be based on

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the use of Duamel's integral.

6. Conclusions

The basic characteristic of the aperture effect is the "law of distribution of a single luminous flux" (1) - the reaction of the scanning system to a single light-pulse function. The law of distribution is connected with the physical parameters of a diaphragm, by the configuration and the "transparency" (or intensity of electron irradiation) of the scanning element. All characteristics used in practice (frequency, pulse, and transitional) are connected with the law of distribution by the simple correlations (5), (10), (13), and (14). The law of distribution and the transmission factor of a harmonic signal are functions which are conjugate according to the Fourier series (5) and (6).

From a pulse characteristic which is in wide use in television practice, namely the transmission factor of a rectangular signal, we may, in a carefully set-up experiment, establish the parameters of the "diaphragm" of the system we are studying: the "diameter" and the law of distribution. From these data, we compose analytical expressions of the frequency or transitional characteristic, and these expressions may be used for the joint examination of all the links of the television tract.

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DEFINING THE PERMISSIBLE AMOUNT OF PERIODIC DISTURBANCE IN THE TELEVISION CHANNEL

by

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Regular member of the Society

Problems of the effect of periodic disturbances on the quality of the television image have not been treated in the literature of this country. In this article, the permissible level of periodic disturbance in the television channel is correlated with some characteristics of the channel and some peculiarities of vision. The results obtained in experimental investigations of these conditions, are described.

1. Image Distortion Due to Periodic Disturbances

Distortions of a television image are usually divided into raster distortions (distortions in form) and modulation distortions (distortions in brightness).

Raster distortions due to periodic disturbance begin to become noticeable when the intensity of the disturbance is at least twice as great as that at which modulation distortions occur.

Modulation distortions due to periodic disturbance show in a change in the brightness and contrast of the image. When the disturbance frequencies are less than about 3 mc, they are local in character and result in a change of brightness in the different portions of the image and in the formation of an interference pattern, which is stationary or which moves across the screen, and which is in the form of alternating dark and light portions. The character of the periodic-disturbance pattern depends on the relationship between the frequency of the disturbance f_p and the frequency of the line (f cmp) and the frame (f_k) scanning, and also on whether or not the disturbance is modulated by the voltage of some other frequency F (see Table).

With an increase in f_p, the width of the bands in the interference pattern STAT

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Table 1

Character of the Periodic-Disturbance Pattern as a Function of the Frequency of Interference

No.	Correlation of f_p and f_k, and f_p and f_{cmp}	Nature of the Interference Pattern
1	$f_p < f_{cmp}$ $f_p = n f_K$	Stationary interference pattern made up of alternating dark and light horizontal bands. The number of pairs of light and dark bands is equal to n (n is a whole number)
2	$f_p < f_{cmp}$ $f_p \neq n f_K$	Horizontal bands moving up or down across the screen
3	$f_p > f_{cmp}$ $f_p = m f_{cmp}$	Stationary vertical bands. The number of pairs of bands is m (m is a whole number)
4	$f_p > f_{cmp}$ $f_p = \frac{2m+1}{2} f_{cmp}$ $f = n f_K$	Pattern of vertical bands, with the dark and light bands in adjacent frames occupying opposite positions. As a result of neutralization by frames, this interference pattern is only slightly distinguishable
5	$f_p > f_{cmp}$ $f_p \neq m f_{cmp}$, но $f_p = n f_K$	Stationary pattern of alternating dark and light inclined bands
6	$f_p > f_{cmp}$ $f_p \neq m f_{cmp}$ $f_p \neq n f_K$	Pattern of inclined bands moving across the screen

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decreases, and they begin to be more difficult to distinguish. There are several reasons for this:

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a) Decrease in the angle at which the eye sees the bands, and, linked with this, an increase in threshold difference in brightness;

b) Decrease in the contrast in small details due to illumination of neighboring portions of the tube screen by diffused light (aureole);

c) Some weakening in the disturbance intensity due to a drop in the frequency characteristic of the channel in the high-frequency area;

d) Aperture distortions in the receiving tube. These begin to show up when the width of the bands in the interference pattern approaches the thickness of the beam.

These circumstances lead to a state where, at the usual distances from the eye of the observer to the screen, a nonmodulated interference with a frequency greater than about 3 mc is preceived not in the form of a pattern imposed upon the image, but in the form of a change in the imago mean brightness and contrast.

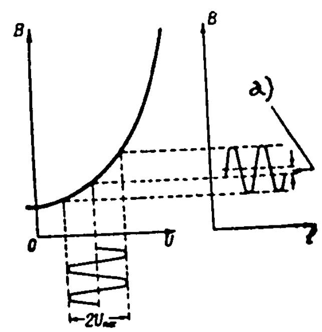

Fig.1

a) Visible increment in mean brightness

Due to the fact that the light characteristic of the receiving tube is not linear, a peculiar "light detection" of the interference takes place, leading to a change (usually an increase) in the mean brightness component (Fig.1). This phenomenon is to some extent analogous to the change in the mean plate current of a tube due to alternating voltage applied to the grid when it works on a nonlinear portion of the characteristic.

Another, more substantial phenomenon is the effect of a high-frequency inter-

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ference on the circuit for re-establishing the mean brightness component. Insofar as the circuits for re-establishing the mean component usually react to the peak voltage, an increase in the height of the interference-produced attenuation pulses leads to a displacement of the entire image signal to the right (Fig.2), which corresponds to an increase in the mean brightness of the image*.

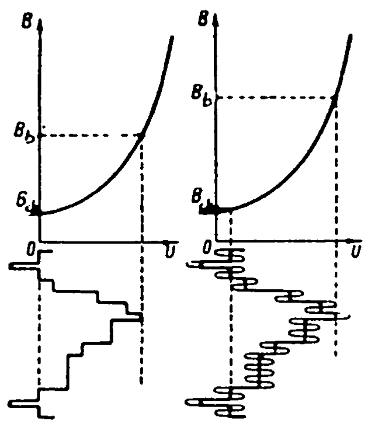

Fig.2

Finally, if the interference frequency is greater than the upper limit of the pass band, the interference cannot immediately pass through the tract. However, in a case where the link on which the interference is acting is nonlinear, beat interferences may occur with the components of the signal, and part of the products of the nonlinearity will then manifest itself in the pass band of the tract. In the case of a modulated interference, detection with elimination of oscillations with the modulation frequency will occur**. We must note that a pattern of horizontal bands caused by modulation of the interference becomes noticeable when $f_p > 3$ mc, i.e., when f_p still lies in the pass band of the channel.

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*This has been confirmed by experiment. The action of the interference leads to another phenomenon, which seems strange at first glance: The darkest brightness-gradation fields, not discernible until then, begin to be distinguishable from one another. Why this occurs is evident from Fig.2. These fields now occur on a steeper portion of the light characteristic, and for this reason the contrast between them is increased.

**This circumstance leads to the requirement of linearity in the amplitude characteristics of the first links of the channel.

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2. Equation for the Permissible Amount of the Signal-to-Noise Ratio

The effect of an interference whose frequency lies in the pass band of the tract may be presented by a certain instantaneous increment ΔU in the signal voltage U, due to the interference. Correspondingly, the visible effect of the interference can be characterized by a certain local increment in brightness ΔB.

Not every brightness increment ΔB is noticeable to the eye. The smallest distinguishable difference in the brightness of an object (interference pattern) and of the background (the portion of the image on which the interference pattern is imposed) is defined as the threshhold difference in brightness B_{thr}. Research has shown that, in a wide range of brightnesses, B_{thr} increases in proportion to the brightness of the background B to which the eye is adapted. In other words, the amount of the difference threshhold is

$$\delta = \frac{\Delta B_{thr}}{B} = \text{const.} \quad (1)$$

Let us connect the permissible amount of the signal-to-noise ratio $(C/P)_{perm}$ in the tract with the permissible amount of relative change in brightness $(\frac{\Delta B}{B})_{perm}$, which we treat as identical to $\delta = (\frac{\Delta B}{B})_{thr}$.

We will try to find

$$\left(\frac{C}{P}\right)_{perm} = \psi \left(\frac{\Delta B}{B}\right)_{thr} \quad \text{or} \quad \left(\frac{\Pi}{C}\right)_{perm} = \xi \left(\frac{\Delta B}{B}\right)_{thr} \quad (2)$$

Let us introduce the following symbols:

B_b is the brightness of the screen corresponding to the lightest portions of the object being transmitted;

B_{ch} is the brightness of the screen corresponding to the darkest portions of the object being transmitted;

U_b is the signal level corresponding to the lightest portions of the object being transmitted (the "white" level);

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U_{ch} is the signal level corresponding to the darkest portions of the object being transmitted (the "black" level);

U_{cm} is the maximum amplitude of the image signal;

$\alpha = \frac{B}{B_b}$ is the relative brightness ($\alpha \leq 1$);

$\beta = \frac{B_b}{B_{ch}}$ is the tube contrast ($\beta > 1$).

Then
$$U_{cm} = |U_b - U_{ch}|;\ B = \alpha B_b;\ B_b = \beta B_{ch};\ B = \alpha \beta B_{ch}. \tag{3}$$

The increment in brightness ΔB, due to the increment in voltage ΔU, depends on the amount of ΔU and on the slope of the light characteristic in the given portion of the characteristic.

Let us represent the light characteristic of the receiving tube in the area where $U > U_{ch}$, by a function

$$B = \kappa U^{\gamma} + B_{ch} \tag{4}$$

and in the area where $U < U_{ch}$, let us represent it by the straight line $B = B_{ch}$ of the parallel axis U (Fig.3)*. Let us construct the ratio of the voltage increment to the original voltage as a function of the ratio of the increment in brightness to the original brightness in differential form. To simplify this construction, let us execute it in the coordinates UB':

$$\frac{dU}{U} = \frac{1}{\gamma} \frac{dB}{B'}. \tag{5}$$

Let us change over to the system of coordinates U B, taking into account the

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*We may often see a representation of the light characteristic of the tube, in which the point corresponding to the "black" brightness lies on the abscissa, i.e., $B_{ch} = 0$. This representation of the characteristic contradicts the physical notion of a finite amount of contrast, since, at $B_{ch} \to 0$, we have $\beta \to \infty$.

fact that

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$$B' \quad B - B_{0}; \qquad dB' \quad dB \tag{6}$$

Let us also express the current value of U by U_{cm} and the parameters α and β. Substituting eq.(6) in eq.(5), and also taking into account the correlations of eq.(3), simple transformations will yield

$$\frac{dU}{U_{cm}} \quad \frac{1}{\gamma} \frac{\alpha\beta}{\sqrt[\gamma]{(\beta-1)(\alpha\beta-1)^{\gamma-1}}} \frac{dB}{B} \tag{7}$$

Let us use eq.(7) to compute that amount of $(C/P)_{perm}$ in the tract at which the interference pattern on the tube screen is at the limit of visibility (is scarcely noticeable).

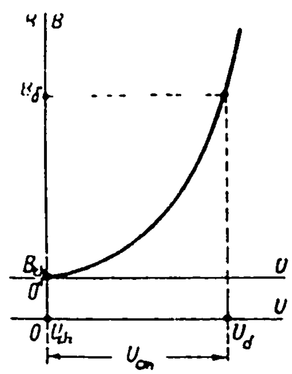

Fig.3

Strictly speaking, expression (7) is correct only for infinitely small increments of U and B. But insofar as, in this case, the interference voltage is considerably less than the signal voltage, we will without a great error replace dB by ΔB, dU by ΔU, and ΔU, in turn, by $2U_{Pm}$ (for sinusoidal interference). Let us also replace $\frac{\Delta B}{B}$ by $(\frac{\Delta B}{B})_{thr} = \delta$. Then,

$$\left(\frac{P}{C}\right)_{perm} = \frac{2U_{Pm}}{U_{cm}} = \frac{\alpha\beta\delta}{\gamma\sqrt[\gamma]{(\beta-1)(\alpha\beta-1)^{\gamma-1}}} = x\delta \tag{8}$$

or

$$\left(\frac{C}{P}\right)_{perm} = \frac{U_{cm}}{2U_{Pm}} =$$

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$$\gamma \frac{\sqrt[\gamma]{(\beta - 1)(\alpha\beta - 1)^{\gamma - 1}}}{\alpha\beta\delta} = \frac{1}{x\delta}, \tag{9}$$

where the factor $x = \dfrac{\alpha\beta}{\gamma \sqrt[\gamma]{(\beta - 1)(\alpha\beta / 1)^{\gamma - 1}}}$ characterizes the danger of a visible interference appearing on a portion of the image with some relative brightness α (for the given tube parameters β and γ), while the factor δ (difference threshold)

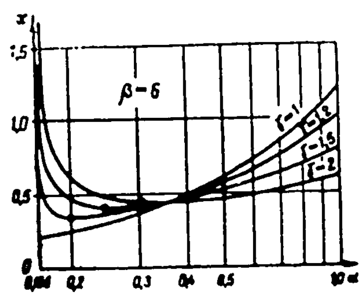

Fig.4

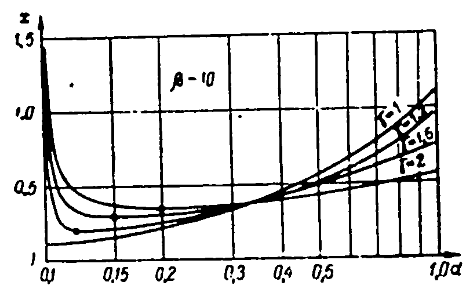

Fig.5

characterizes the danger of an interference depending upon the angular dimensions of the parts of its pattern, i.e., depending upon the structure of the interference pattern.

The smaller the value of x, the smaller should be the ratio $(P/C)_{perm}$, i.e., the smaller will be the permissible interference level in the tract.

The results of computation of x are presented in Figs.4 and 5. A sharp rise in the x curves is characteristic when the values of α approach $\frac{1}{B}(B - B_{ch})$. This path of the curves, somewhat strange at first glance, becomes understandable when we examine the approximating curve. As B approaches B_{ch}, the slope of the curve approaches zero; at the limit, when $B = B_{ch}$, it is equal to zero, and small increments in stress cause no change in brightness.

The curves are at a minimum at the comparatively small values of α (but not the smallest values). Thus the most dangerous portions of the image relative to the

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appearance of visible interferences are those with an intermediate amount of brightness ("gray" portions) but not those with the minimum brightness $B = B_{ch}$*.

From Figs.4 and 5 it is evident that an increase in contrast in the tubes imposes more rigid requirements as to the amount of $(C/P)_{perm}$ in the tract.

We should devote particular attention to the problem of the amount of the difference threshold δ. In television, the accepted amount is $\delta = 0.02$ (2%). However, this value of the difference threshold is correct only for distinguishing objects with comparatively large angular dimensions (of the order of several degrees; see Bibl.1). The value of the difference threshold depends to a large extent upon the angular dimensions φ of the objects being distinguished, which in this case are the alternating dark and light bands of the interference pattern; it also depends to a large extent upon the brightness of the background B.

$$\delta = F(\varphi, B). \tag{10}$$

By setting the different values of the background brightness we can obtain the dependence of the difference threshold upon φ. These dependences were obtained by A.A.Smirnov for round objects (Bibl.2) and by M.Lekish for objects in the form of alternating light and dark bands (Bibl.1). The second dependence (Fig.6) is used for a 10-msb background brightness, and this corresponds approximately to the mean brightness of a receiving tube screen, for computing δ in a case where the inter-

*In deriving eq.(8), we assumed that the amount of the difference threshold δ remains constant within the limits of the entire range of change in brightnesses. This is correct for sufficiently bright television images. When the brightness of the object is slight, the difference threshhold increases, i.e., the eye's sensitivity to distinction in contrasts is reduced. This circumstance increases still further the danger of visible interferences appearing on the darkest portions of the image.

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ference pattern is in the form of bands.

The angular dimension of the width of a band in an interference pattern can easily be connected with the frequency of the interference. Thus the graph of Fig.6 can express at a certain scale the dependence of the difference threshold on the interference frequency, i.e., the dependence (10) is converted into a dependence having the form

$$\delta = \Phi(f_p, B). \qquad (11)$$

Then, eq.(9) may be written in the form

$$\left(\frac{C}{P}\right)_{perm} = \frac{\sqrt[\gamma]{(\beta-1)(\alpha\beta-1)^{\gamma-1}}}{\alpha\beta\,\Phi(f_p, B)}. \qquad (12)$$

This expression is used in computing the permissible amount of C/P in the television tract. Calculations have shown that the most dangerous interferences are those with a frequency of less than 0.5 mc, for which the angular dimensions of the bands are more than 10'. In this area, the curve of $\delta = F(\varphi, B)$ is almost horizontal. With an increase in frequency and, consequently, a reduction in the width of the bands, δ increases sharply.

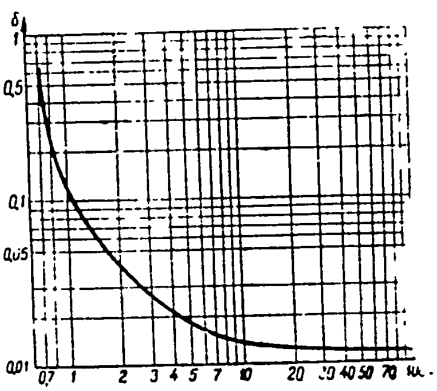

Fig.6

In spite of the fact that the above analysis has yielded an explanation for a number of connections between the permissible interference level in the tract and certain characteristics of the tract and peculiarities of visual perception, this analysis cannot be considered exhaustive. For this reason, the theoretical considerations were checked by

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experiment.

3. Results of Experiments

The distinguishability of the patterns of periodic interference was investigated on frequencies, multiple to the line frequency, or close to multiple frequencies. This case is close to the theoretically examined case.

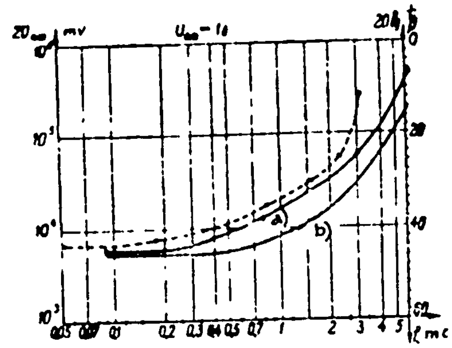

Fig.7

a) Experiment; b) Computation

The results of the experiments are presented in the graph of Fig.7. Along the horizontal axis are plotted the interference frequencies, in megacycles, and along the vertical axis (scale on the left) are plotted doubled interference amplitudes, relative to the magnitude of the total amplitude of the image signal of 1 volt. The graph also expresses the dependence of C/P in decibels on the interference frequency (right-hand scale).

The computation curve is constructed according to the parameters of the tube used in the experimentation ($\gamma = 1.5$, $\beta = 6$) and is most unfavorable in the case of the data for γ and β in reference to the brightness of the portion of the image on which the interference pattern appears ($\alpha = 0.25$).

The experimental curve has the same character as the calculated curve, but it lies somewhat higher; the divergence increases with increasing frequency. The reasons for the divergence may be:

a) The computation curve was constructed on the supposition that there is a sharply defined border between the dark and light portions of the interference pattern; the presence of a vaguely defined border, due to the sinusoidal form of the interference voltage, leads to an increase in δ, i.e., to a reduction in the

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definition of the interference pattern*;

b) The computation curve was constructed on the assumption that the interference pattern is stationary; a slow movement in the pattern increases its definition.

Inasmuch as the experimental curve passes higher than the computation curve, it is clear that the first of these two reasons is the most important.

In order to affirm this, we used a generator of rectangular pulses as a source of interference in one of the experiments, to establish the amount of $(C/P)_{perm}$. The repetition frequencies were established as being the same as the frequencies of the sinusoidal interference. The values of the $(C/P)_{perm}$ ratio obtained here coincide with the computation curve in the area of comparatively low frequencies; however, in the area of higher frequencies this value, although lying below the experimental curve, still deviates increasingly from the computation curve.

This is explained by the fact that, as we reduce the dimensions of neighboring fields being compared, their contrast decreases due to the aureole. This circumstance was not taken into account in our computations (β was taken as a contrast), since no quantitative study was made of the character of the change in contrast in the parts, as dependent upon their dimensions.

At the extreme reference frequencies (3.2 and 6.4 mc), when the width of the bands in the interference pattern becomes commensurate with the thickness of the beams, aperture distortions in the receiving tube may play a certain role.

The results we obtained were compared with the results of a study (Bibl.4) made for the British television system (405 lines). Inasmuch as the visible effect of the interference is determined by the angular width of the bands of the interference pattern, the comparison of the C/P values was made not at equal interference

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*The presence of a vaguely defined borderline between the fields of different brightness has a comparatively slight effect upon the amount of δ only when the [redacted] large dimensions, of the order of 2 or 3° or more. STAT frequencies, but at equal angular dimensions of the bands. Values of C/P for the "barely perceptible interference" estimation are shown in Fig.7 (dotted curve).

The divergence in the high-frequency zone may be explained by the greater aperture distortions in the system and by the lower degree of clarity due to the great thickness of the beam.

We must point out the mistake of the authors of another paper (Bibl.4); they explain the change in the image brightness and contrast, due to the effect of an interference whose frequency lies in the upper part of the pass band, by "overmodulation" of the tube. In reality the amount of interference voltage at which this phenomenon starts to show up is 10 - 20 times less than the signal voltage, so that there can still be no question of overmodulation. In actual fact, the principal role in this phenomenon, as has been shown above, is played by the effect of the interference upon the restorer circuit of the mean brightness component. The authors of Bibl.4 mistakenly assume that the amount of the difference threshold is a constant.

4. Conclusions

From theoretical and experimental investigations on the effect of periodic interferences, the following conclusions can be drawn:

a) The amount of $(C/P)_{perm}$ in the tract and, consequently, the amount of permissible interference voltage in the tract, may be obtained by computation on the basis of knowing certain characteristics of vision (chiefly the difference threshold) and on the basis of the form of the amplitude characteristic of the tract, including the receiving tube.

b) The definition of an interference pattern depends upon the relative brightness of that portion of the image upon which the interference pattern is superposed. The most dangerous fields are the "gray fields" with relative brightness of the order of 0.2 to 0.3 (when the contrast in details is $\beta = 6$) or 0.12 - 0.2 (when $\beta = 10$).

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c) Results of computation have shown that, with an increase in γ in the receiving tube, $(C/P)_{perm}$ decreases, i.e., there is an increase in the permissible amount of interference voltage in the tract. In addition, when γ increases to 2 - 2.5, the amount of $(C/P)_{perm}$ is approximately constant through almost the entire range of change in relative brightness. For this reason, in order to reduce the definition of the interference pattern it is desirable to increase γ to 2 - 2.5.

d) For a periodic disturbance which sets up a pattern in the form of vertical or slightly inclined bands, the amount of $(C/P)_{perm}$ is equal to 45 - 46 db at frequencies lower than 0.2 mc, and this amount decreases with increasing frequency, until it is approximately 16 db at the upper limit of the pass band (for tubes with $\beta = 6$ and $\gamma = 1.5$). This theoretical conclusion has been confirmed by experimentation.

e) An increase in the tube contrast (in details), desirable from the point of view of overall increase in the quality of the television image, requires an increase in the $(C/P)_{perm}$, i.e., a reduction in the permissible amount of interference voltage in the tract. Thus, if we succeeded in making a tube with a detail contrast of $\beta = 50$, then in the area of interference frequencies of $f_p < 0.2$ mc, the quantity $(C/P)_{perm}$ would have a value of the order of 500 (54 db), i.e., about 8 db more than for existing tubes.

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USE OF ANALYTICAL COMPUTERS FOR STATISTICAL ANALYSIS OF TELEVISION MESSAGES

by

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V. A. Garmash,

D. S. Lebedev

The author shows the possibility of using analytical computers to obtain polydimensional functions of the probability distribution in the gradations of brightness of a television message. Sections of motion picture films were used as the television message. For two frames he cites a one-dimensional function of the probability distribution, a function of correlation, and the value of the entropy reckoned according to a two-dimensional function of the probability distribution.

To make the information source agree with the communication system we must know the rate at which the source produces information (Bibl.1 and 2).

The rate at which messages are set up by any source is determined by the statistical structure of a great number of messages (Bibl.3), and this structure is described by assuming polydimensional probability distributions for the appearance of some groups of message elements. Each group is distinguished by the choice of the values of the elements entering into it.

A television message is a sequence of frames - a sequence of stationary images. For this reason, a section of motion picture film may be considered a recording of a television message. Here the value of one or another element is the magnitude of the video signal in the transmission of a given element, and this magnitude is proportional to the coefficient of transparency of the corresponding image elemenSTAT

The number of elements in an image (a motion-picture frame) is selected in accordance with the television standard of about 350 to 400 thousand. The value of the coefficient of transparency of each element is apportioned into eight levels (gradations), and all the levels divide the range of change in this coefficient into equal parts. The recording of the quantized signal is subjected to statistical analysis in order to determine the one-dimensional and two-dimensional distribution functions, the correlation functions, and the values of entropy for the different subjects.

Work done by statistical analysis of the messages, pre-supposes the following two operations: 1) sorting the entire message into groups according to definite criteria and 2) calculating the number of groups with the same attributes.

This work should be mechanized, since manual handling of the material requires a considerable amount of time and leads to impermissible errors. For a statistical analysis it is desirable to use computers. However, high-speed universal computers are not suitable for this work* (small capacity of internal memory, lack of effectiveness in working with constant use of external memory). When there is a large number of results, analytical computers can be used. A whole set of analytical computers works on data which have been entered on punch cards, and for this reason the values of the coefficients of transparency of the different elements in the image which is being studied should be entered on these punch cards.

The work done by statistical analysis of images is divided into two parts: distributing and recording the values of the coefficients of transparency of the brightness of the different elements on an intermediate carrier, for which we use a standard telegraph-type punched tape, and transferring the data from the punched tape onto the punch cards and then handling the cards on the analytical computer.

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*Special high-speed computers (electronic sorters) are available only in single specimens and are not practical for general use.

The block diagram of an installation for recording the values of the coefficient of transparency of the image elements, as worked out by one of the authors of this article (Bibl.4), is shown in Fig.1.

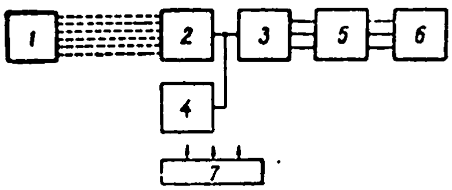

Fig.1

The image (of the motion-picture film) being studied here, is moved in jumps by the automatic tape winder (1). A light passes through the image and falls on the photomultiplier (2), which is erected at the input of the cathode repeater. The output of the repeater furnishes a photosignal which is proportional to the quantity of the light incident on the photomultiplier, and consequently is proportional to the coefficient of transparency of the corresponding image element; this photosignal is fed to the input of the quantizer (3), where it is combined with the sinusoidal signal of the sound generator (4).

The quantizer has three outputs, at each of which, depending upon the intensity of the photosignal, there may or may not be the sinusoidal voltage which is supplied to the input. The interval in the values of the photosignal is broken down into eight parts, so that a definite combination of presence and absence of voltages at the outputs (in all there are 2^3 such combinations, i.e., $2^3 = 8$) corresponds to the photosignal, which may have any value within the limits of the given part.

The outputs of the quantizer are connected to the inputs of the relay-amplifier system (5), which consists of three similar channels. In each channel, the sinusoidal signal from the quantizer is amplified and acts on the output relay in such a way that when there is a signal in the given channel the relay is tripped, closing the output contact.

Thus each combination of open and closed outputs on the quantizer is reproduced by the closed and opened contacts of the output relays. These contacts are

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10 placed in the circuit of a telegraph start-stop apparatus, together with the perforator (6). The punches of the perforator whose circuits are closed by the output contacts make holes in the paper tape. After the given combination is punched, the telegraph apparatus sends a pulse to the automatic tape winder, which moves the image for analysis of the next element.

At the computation station, the data deposited on the punched tape are automatically transferred to the punch cards. This is done by a special device whose design is based on the telegraph transmitter (Bibl.5). The punched tape is entrained between the counting brushes, and when there is a hole in the tape the decoder circuit closes. This is necessary in order to transfer the numbers from the binary system of calculation to the eight-digit positional system. The circuits of the decoder close the circuits of the blocking magnets of the sum perforator which punches the cards. The basic amount of punch cards, with the entered data, may be multiplied with the help of a reproducer, which shortens the handling time of the original material, as shown in Bibl.6. The multiplied amount of cards is sorted on sorting machines which replace hand labor, in grouping the cards according to definite criteria.

Grouping the punch cards according to a criterion of many categories requires that the lot of cards be passed through as many times as there are categories in the criterion: thus, determining two-dimensional distribution functions ($8^2 = 64$ results) requires that the entire lot of punch cards pass through sorting two times. Once sorted, the lot of punch cards goes to the tabulator, which counts the number of similar cards in a group and prints the results on a paper tape, known as a tabulogram.

We treated two subjects to statistical analysis: No. 1 is a large-scale face and No. 2 is a cottage and garden.

From each face we counted off and recorded five thousand elements, i.e., not all the frame scanning elements were used in the analysis. In Fig.2 we show the

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one-dimensional functions of the probability distribution for the two subjects.

For a case where the number of gradations in brightness was chosen to be equal to eight, the maximum entropy is equal to $H_0 = \log 8 = 3$. For the subjects studied, we obtained the following results: for subject No. 1, H = 0.64; for subject No. 2, H = 0.78.

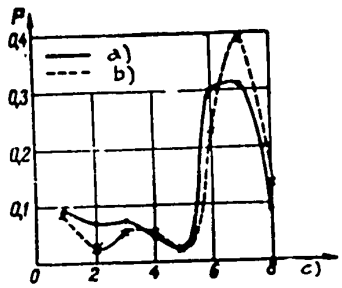

Fig.2

a) Subject No. 1; b) Subject No. 2;
c) Gradations

The relative entropy $H' = \frac{H}{H_0}$, obtained for each subject, is equal to 0.213 and 0.26, respectively.

A study of two-dimensional functions of the probability distribution in the brightness gradations not only of neighboring image elements, but also of those located at definite distances (through one, two, etc., to the fortieth element), has made it possible to construct correlation functions for these systems, and these functions are shown in Fig.3.

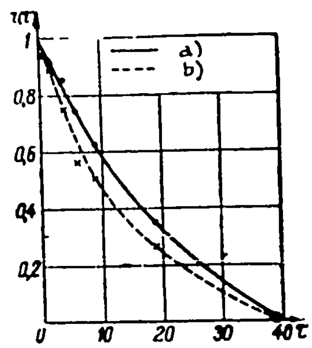

Fig.3

a) Subject No. 1; b) Subject No. 2

The study method presented here and the equipment constructed by us make it possible to study functions of probability distribution of a higher order. Since eighty different decimal numbers may be deposited on each punch card, then in principle the functions of the probability distribution can be studied to the eightieth order.

The device designed by us for recording images on punched tape makes it possible to perform a quantizing into 32 levels.

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In conclusion, the authors express their appreciation to the "Stal'proyekt" Institute, which offered them the possibility of working at their computer station, and to their fellow LPS workers T.A.Belotserkovskiy, K.N.Budtalayev, and M.M.Leonova for setting up the installation and working out the results.

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ON THE SELECTION OF VIDEO AMPLIFIERS

by

Yu. N. Prozorovskiy

Regular Member of the Society

The author discusses the fields in which it is expedient to use corrected RC-amplifiers and amplifiers with distributed constants. He also determines the most advantageous number of stages and the minimum duration of the front of the transfer characteristic of the corrected amplifier as well as the conditions for a rational distribution of tubes in a multistage amplifier with distributed constants.

1. Introduction

In 1948 there appeared descriptions of new broad-band amplifiers with distributed constants (Bibl.1) and with a band of frequencies up to 150 or 200 mc. At that time, it was impossible to obtain such a wide frequency band with the known corrected RC-amplifiers. Production of radio tubes with a steep characteristic slope (such tubes were worked out in the following years) permits us to considerably broaden the area in which corrected amplifiers may be used, and in many cases permits the use of corrected amplifiers to replace complex amplifiers with distributed constants.

2. Minimum Duration of the Front of a Corrected RC-Amplifier Transfer Characteristic

The duration of the front of the transfer characteristic of a single-stage, uncorrected RC-amplifier is defined by the expression

$$\tau_1 = 2{,}2\,RC, \qquad (1)$$

where R is the plate load of the tube and C is the sum of the output capacitance of the tube, the input capacitance of the following tube, and the capaci STAT

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of the assembly.

Let us introduce the coefficients

$$\alpha = \frac{S}{C} \text{ and } \beta = \frac{\tau_1}{\tau_{1k}}. \qquad (2)$$

The coefficient α characterizes the quality of the stage of a broad-band uncorrected amplifier which has a tube with a transconductance S and a total capacitance C. We will call this the quality factor. The coefficient β characterizes the effectiveness of the correction and shows how many times the duration of the front of the transfer characteristic of the corrected stage τ_{1k} is less than the duration of the front of the same stage without correction. We will call β the correction factor.

The duration of the front of the transfer characteristic of a multistage corrected amplifier consisting of N similar stages is $\tau_{ky} = \tau_{1k} N^{\frac{1}{2}}$. We note that in this case the condition that $R \ll R_i$ is satisfied; then

$$\tau_{ky} = \frac{2,2}{\alpha\beta} N^{\frac{1}{2}} K^{\frac{1}{N}}, \qquad (3)$$

where K is the overall amplification factor.

The most advantageous number of stages in a corrected amplifier N_{opt}, which is necessary in order that the minimum value of τ_{ky} be obtained, is determined by finding the minimum for eq.(3)

$$N_{opt} = 2 \ln K. \qquad (4)$$

Hence

$$\tau_{ky\,min} = \frac{7,78}{\alpha\beta} \sqrt{\lg K}. \qquad (5)$$

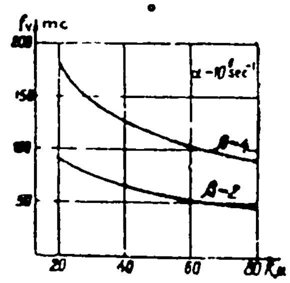

Fig.1

Equation (5) permits determining the lowest values of τ_{ky} which may be obtained

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by using different tubes and correction circuits characterized by the coefficients α and β; consequently, the expression establishes the limits of the field in which corrected amplifiers may be used in any concrete case. Figure 1 shows the approximate limits of the frequency characteristics of multitube corrected amplifiers (when the obstruction on f_v is equal to 3 db); these limits are calculated according to eq.(5).

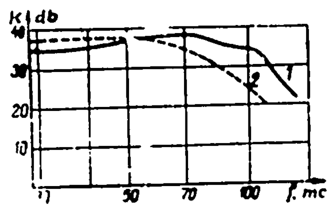

Fig.2

In this case,

$$f_b = \frac{b}{\tau}. \tag{6}$$

Here we have assumed that $\alpha = 10^9\ \text{sec}^{-1}$ (for a 6Zh9P tube, $S = 15 - 18\ \frac{\text{ma}}{\text{v}}$ and $C \approx 15\ \mu\mu f$ or, for a 6E5P tube, $S = 25 - 30\ \frac{\text{ma}}{\text{v}}$ and $C \approx 25\ \mu\mu f$) and that $b = 0.35$. The curves actually correspond to attainable values of f_b when the correction is of the quadripole ($\beta = 4$) or dipole type ($\beta = 2$).

In order to check these results by experiment, we constructed two broad-band RC-amplifiers with dipole correction and with amplification of the order of 35 - 38 db in 6Zh9P tubes, with the following data:

1) N = 6, pass band 1500 cycles to 110 mc;

2) N = 7, pass band 15 kc to 80 mc.

The frequency characteristics of the amplifiers are shown in Fig.2; the circuit of the amplifier (1) differs from that of the amplifier (2) by the presence of grid circuits of additional series resistances, introduced in order to improve the transfer characteristic.

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3. Optimum Number of Tubes in an Amplifier with Distributed Constants

Ginzton and others (Bibl.1) have shown that, in a multistage amplifier with distributed constants, the lowest number of tubes will occur in the case where the amplification factor of one stage is equal to e. This conclusion was reached for the particular case where the amplifier stages are coordinated with the help of transformers, which are tubeless devices with a definite transmission factor. Let us examine a more general case.

In Fig.3 we show the block diagram of a multistage amplifier with distributed constants; the amplifier consists of m uniform stages, each of which has n tubes, and m matching devices SU, which coordinate the stages and which have p tubes each. The overall amplification factor of such an amplifier is

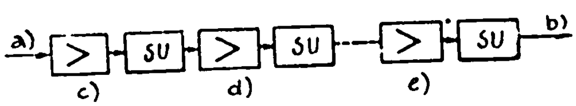

Fig.3

a) Input; b) Output; c) 1st amplification stage; d) 2nd amplification stage; e) mth amplification stage

$$K = K_k^m \cdot K_c^m = (K_1 n K_c)^m, \tag{7}$$

where K_k is the amplification factor of one stage.

K_1 is the amplification factor of one section, and

K_c is the transmission factor of the matching device.

Then the number of tubes in one stage will be

$$n = \frac{K^{\frac{1}{m}}}{K_1 K_c}, \tag{8}$$

and the total number of tubes in the amplifier

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$$N = (n + p)\,m = \frac{m}{K_1K_c}\,K^{\frac{1}{m}} + pm. \tag{9}$$

Let us introduce the coefficient $\gamma = K_c p K_1$, which characterizes both the matching devices and the degree to which the tubes are used in the amplifying stages, and determine the optimum number of stages by finding the minimum for eq.(9). Then

$$m_{opt} = \frac{e \ln K}{e + \gamma Z}, \tag{10}$$

where Z is the parameter determined from the expression $Z \cdot 1.443^{\gamma Z} = 1$ or from the graph of Fig.4.

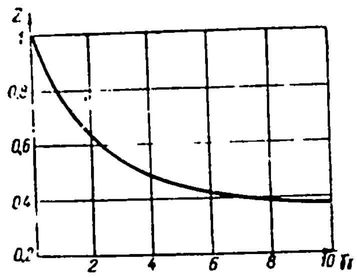

Fig.4

When the values of γ and K are known and the value of m is optimum, eqs.(8) and (9) can be used for determining the number of tubes in one stage and in the entire amplifier, when they are most advantageously distributed throughout the stages. The case examined in Bibl.1 corresponds to $\gamma = 0$; in this case, $m_{opt} = \ln K$

Often the optimum number of tubes in one stage should be of the order of but a few units. In this case, one of the basic conditions for setting up an amplifier may be broken; according to this condition, n should be so large that the plate circuit and the grid circuit can be considered lines with evenly distributed constants. Let us examine the case where the minimum permissible value of n is selected, being equal to n_{min}.

The overall number of tubes in a multistage amplifier with matching transformers is

$$N = mn = mK^{\frac{1}{m}}\,\frac{2f_v}{f_0}, \tag{11}$$

where $f_0 = \frac{S}{\pi C_1}$, C_1 being the capacitance of one cell of the line.

Let us denote $\frac{S}{C_1}$ by α_1. Then, $n = K^{\frac{1}{m}} \frac{2\pi f_v}{\alpha_1} = n_{min}$.

Let us denote $\frac{n_{min}\alpha_1}{2\pi f_v}$ by δ; we will then obtain

$$m = \frac{\lg K}{\lg \delta}, \tag{12}$$

whence

$$N = n_{min} \frac{\lg K}{\lg \delta}; \quad K = \left(\frac{\tau_1 n_{min}}{2\pi f}\right)^{\frac{N}{n_{min}}}. \tag{13}$$

4. Comparison of the Corrected Amplifier and the Amplifier with Distributed Constants

We will compare the amplifiers, assuming that they are based on uniform tubes, that the input and output capacitances of the tubes are equal, and that the capacitances of the assembly of the plate and grid circuits are the same. In this case, $\alpha_1 = 2\alpha$. We will also consider that the duration of the front of the transfer characteristic of the amplifier with distributed constants τ_{py}, and its highest operating frequency f_v (at a 3-db obstruction), are correlated approximately by eq.(6). Then, by reorganizing eq.(13), we will obtain

$$\tau_{py} = \frac{b\tau}{a\, n_{min}} K^{\frac{n_{min}}{N}} \tag{14}$$

Let us determine the number of tubes N_τ at which both amplifiers have transfer characteristics with equal durations of the front ($\tau_{py} = \tau_{ky}$). From eqs.(14) and (3) we obtain

$$N_\tau^{\frac{1}{2}} K^{\frac{1-n_{min}}{N_\tau}} = \frac{b\tau\beta}{2,2n_{min}}. \tag{15}$$

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Let us note that N_τ in eq.(15) does not depend upon the coefficient α and consequently does not depend upon the type of tubes.

From eqs.(15) and (14) or (3) we may determine the value of f_{gp} at which the amplifiers of both types have an equal number of tubes and the same transfer characteristics.

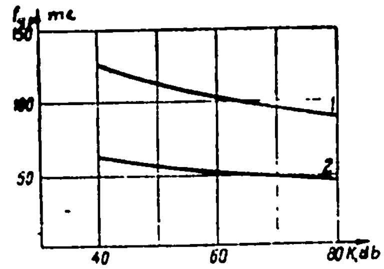

Fig.5

Figure 5 illustrates the $f_{gp} = F(K)$ dependences for amplifiers on 6Zh9P or 6E5P tubes (curve 1) and on 6Zh1P or 6Zh3P tubes (curve 2) when the correction is of the quadripole type ($\beta = 4$) and when $b = 0.35$ and $n = 4$.

In the areas below the curves in Fig.5 it is suggested to use amplifiers with distributed constants, since in this case the corrected amplifiers have less tubes. Above the curves in Fig.5 are areas where we recommend using amplifiers with distributed constants, since in this case corrected amplifiers are more complex or are impossible to construct.

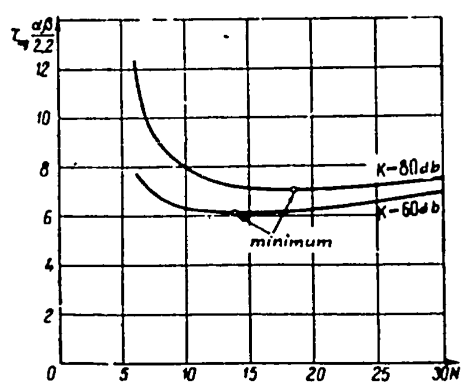

Fig.6

In comparing Figs.1 and 5 it is evident that the f_{gp} curves are located very near the f_v curves, due to the slow variation in τ_{ky} near its minimum (see the example in Fig.6).

Consequently, the following expression is a condition for the usefulness of corrected amplifiers at the given value of K:

$$\tau_{given} > \tau_{ky\,min} \qquad (16)$$

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Example. Given: f_v = 80 mc; K = 80 db; 6Zh9P tubes. To be determined: basic data of the amplifier. In this example the condition (16) is satisfied so that corrected amplifiers should be used. The number of stages is N = 10. The same kind of amplifier with distributed constants and with matching transformers (when n = 4) will have 16 tubes (m = 4).

If f_v is increased to 160 mc, then the condition (16) is not satisfied, i.e., we must select an amplifier with distributed constants. For this, 20 tubes will be required (m = 5).

5. Conclusions

1. It is suggested to use corrected RC-amplifiers in all cases where the given duration of the front of the transfer characteristic is more than the minimum front duration assured by such amplifiers. When $\tau_{given} < \tau_{ky\ min}$, we must use amplifiers with distributed constants.

2. Present-day tubes permit construction of corrected RC-amplifiers with a frequency band up to 200 or 300 mc when the values of K are small, and with a frequency band up to 100 or 150 mc when the values of K are comparatively large.

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A STUDY OF THE PULSE LIMITER

by

S. N. Krize

Regular Member of the Society

In this article the author analyzes the operation of a pulse video-signal limiter. In particular this investigation takes into account the fact that the voltampere characteristic of the limiter element is nonlinear and that the time it takes for the acting pulse to accumulate is finite.

Pulse limiters are widely used in various systems for forming pulses. In spite of this, their theory and computation has not been fully treated in the literature. Let us discuss one of the most widely used schematics for a pulse maximum limiter, as shown in Fig.1a. The operating principle of this circuit, as we know, is based on making use of the nonlinearity of the current characteristic of the tube grid. The grid current generation is accompanied by a sharp reduction in the input resistance of the tube, and this is the reason why further accumulation of voltage on the tube grid is stopped. The diode maximum limiter (schematic in Fig.1b), in which only the subsequent amplification of the pulse is absent, works under analogous conditions.

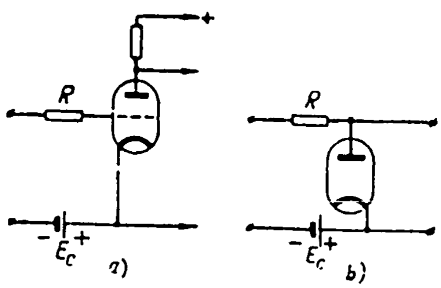

Fig.1

First let us examine the operation of the circuit for those instants of time when the input voltage has not yet reached the limit level, i.e., when $u_c < 0$ and the current in the grid circuit is equal to zero or is insignificantly small. If we limit a pulse with an infinitely small duration of front build-up, then the

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voltage on the grid, evidently, will change according to the following law:

$$u_c = U_m\left(1 - e^{-\frac{t}{\tau_v}}\right), \qquad (1)$$

where $\tau_v = C_o(R + R_i)$ is the time constant of the input circuit of the limiter. Using the Dyuamel' integral k (1), we may show that, for a voltage with a linear build-up, the following expression is valid:

$$u_c = U_m\frac{\tau_v}{t_1}\left(\frac{t}{\tau_v} + e^{-\frac{t}{\tau_v}} - 1\right). \qquad (2)$$

The linear voltage build-up, with satisfactory accuracy, leads to an approximation of segments of the many curves which have an effect upon the limiter under service conditions. Equations (1) and (2) for the obtained voltage are valid for the time from the beginning of the pulse action to the appearance of the grid current of the limiter tube; they permit determining the value of the permissible time constant τ_v and consequently defining the amount of resistance which is inserted consecutively into the limiter circuit.

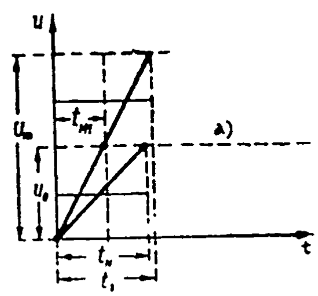

Fig.2

a) Limitation threshold ($u_c = 0$)

As the basic data in computing we should use: the permissible time of build-up of the pulse on the tube grid of the limiter t_n, the spurious shunt capacitance C_o, the equivalent internal resistance of the source of input voltage R_i, and the duration of the front of the input pulse t_{n1} which is being limited (when its value is finite). Let us first examine the case where the emf at the input of the limiter has a linear build-up character within limits somewhat exceeding the limitation threshold u_o, as shown in Fig.2.

If $\tau_v \neq 0$, then the grid voltage will build up within the limits of the varia-

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tion in u from 0 to u_o, according to eq.(2).

When $t = t_n$, the voltage u_c reaches the limitation threshold

$$u_c = u_0 = U_m \frac{\tau_v}{t_1}\left(\frac{t_n}{\tau_v} + e^{-\frac{t_n}{\tau_v}} - 1\right). \qquad (3)$$

The emf of the input source reaches the same value in a shorter time t_{n1}, which is the time of build-up of the input pulse

$$u_0 = \frac{t_{n1}}{t_1} U_m. \qquad (4)$$

Comparing eqs.(3) and (4) we will obtain

$$t_{n1} = t_n - \tau_v\left(1 - e^{-\frac{t_n}{\tau_v}}\right). \qquad (5)$$

Let us denote the ratio $\frac{t_n}{t_{n1}}$ by γ. The value of γ is the attenuation factor of the time of build-up of the input pulse in the limiter, due to the spurious capacitance C_o. Then,

$$\gamma = \frac{1}{1 - \frac{\tau_v}{t_n}\left(1 - e^{-\frac{t_n}{\tau_v}}\right)}. \qquad (6)$$

Since t_{n1} is known, we may select a value for γ and find the time constant τ_v which will ensure the necessary slope of the build-up front of the grid voltage u_c. But it is impossible to obtain τ_v from eq.(6) by algebraic means when $\frac{t_n}{\tau_v} \approx 1$. For this reason, a graph is plotted in Fig.3 for this formula, with whose help it is easy to find $\frac{t_n}{\tau_v}$ for the selected value of the coefficient γ.

For small values of the attenuation factor of the pulse front γ, i.e., when $\frac{t_n}{\tau_v} \gg 1$, eq.(6) may be simplified. In this case $e^{-\frac{t_n}{\tau_v}} \ll 1$, so that

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$$\gamma = \frac{1}{1 - \frac{\tau_v}{t_n}}. \qquad (7)$$

whence

$$\tau_v = t_n\left(1 - \frac{1}{\gamma}\right). \qquad (8)$$

If an emf of rectangular shape (Fig.4) acts at the input of the limiter, then determining the time constant τ_v for the given build-up time t_n is made simple. In this case, the grid voltage varies according to eq.(1). When $t = t_n$, $u_c = u_o$, and for this reason

$$u_0 = U_m\left(1 - e^{-\frac{t_n}{\tau_v}}\right) \qquad (9)$$

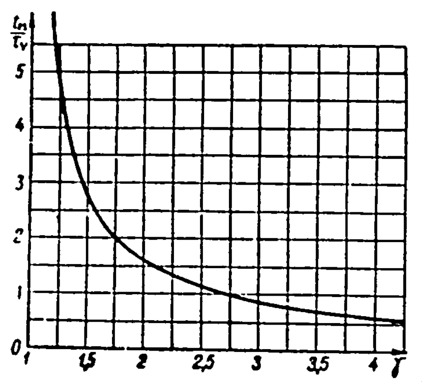

Fig.3

Solving eq.(9) with respect to τ_v will give

$$\tau_v = \frac{t_n}{-\ln\left(1 - \frac{u_0}{U_m}\right)}, \qquad (10)$$

where $\frac{u_o}{U_m}$ is the relative limitation threshold.

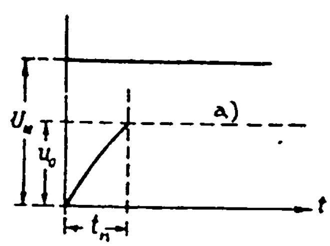

Fig.4

a) Limitation threshold

Having determined τ_v, we find the maximum permissible series resistance R from the formula

$$R = \frac{\tau_v}{C_0} - R_i'. \qquad (11)$$

From the instant the grid current of the tube becomes sufficiently large and cannot be neglected, the grid voltage starts to vary according to another law.

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Taking the effect of the grid current into account may become necessary even for small negative values (of the order of tenths of a volt) of the voltage u_c, if the limiting resistance R is sufficiently large. Inasmuch as, for the limiter to operate it is necessary that the resistance R considerably exceed the resistance of a portion of the filament grid of the tube when $u_c > 0$, we may consider a current pulse I_m to be acting in the circuit of Fig.5. For grid voltages close to zero, the grid current characteristic may be approximated by the exponential function

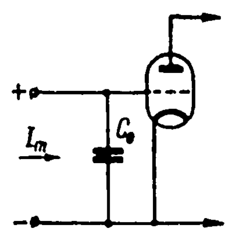

Fig.5

$$i_c = i_0 e^{a u_c} . \tag{12}$$

Then we may determine the grid voltage, while taking into account the effect of the nonlinearity of the grid current characteristic, by using a nonlinear differential equation which describes the capacitance load

$$C \frac{du_c}{dt} + i_0 e^{a u_c} = I_m . \tag{13}$$

Integrating this equation we obtain, after transformation,

$$u_c = \frac{1}{a} \ln \frac{1}{\left(e^{a u_0} - \frac{i_0}{I_m}\right) e^{-t \cdot \frac{a I_m}{C_0}} + \frac{i_0}{I_m}} , \tag{14}$$

where I_m is the amplitude of the current pulse,

and u_0 is the limitation threshold ($u_0 < 0$).

From (14) it follows that the maximum grid voltage, which exceeds the arrestation threshold, is equal to

$$U_{cm} = \frac{1}{a} \ln \frac{1}{\left(e^{a u_0} - \frac{i_0}{I_m}\right) e^{-t_u \frac{a I_m}{C_0}} + \frac{i_0}{I_m}} , \tag{15}$$

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where t_u is the duration of the current pulse.

If a sufficiently long pulse is subjected to limitation, i.e., if

$$t_u \gg \frac{C_0}{aI_m}, \tag{16}$$

then

$$e^{-t_u \frac{aI_m}{C_0}} \ll 1$$

and

$$U_{cm} = \frac{1}{a} \ln \frac{I_m}{i_0}. \tag{17}$$

The task of computing the voltage curve in the limiter is substantially complicated if a separating capacitor C (Fig.6) is inserted in the grid circuit of this tube.

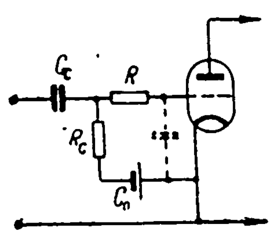

Fig.6

This type of variant in the circuit of the limiter is widely used in actual practice, since it must be used in all cases where the limiter voltage is supplied from the plate circuit of the tube of the preceding stage with elements of a rheostat-capacitance connection.

The build-up front of the grid voltage pulse does not depend upon the presence of a separating capacitor; the capacitance of the latter is always sufficiently large and the time of the charge is incommensurately greater than the time of the capacitance charge C_0. The voltage in the capacitor C begins to change noticeably only after the current appears in the grid circuit of the limiter tube.

If the resistance R is sufficiently large and if it can be assumed that a

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direct current pulse I_m is acting in the circuit shown in Fig.6, then the capacitor charge voltage is defined by the equation $u_c = \frac{1}{C} \int idt = \frac{I_m t}{C}$, i.e., it builds up linearly in time.

But the increase in voltage in the capacitor C in this case has no effect upon the character of the change in the grid voltage of the tube, which builds up in accordance with the equation which approximates the grid-current characteristic. For the initial segment of the characteristic, if we approximate it in the form of an exponential function, we will obtain an increase in the grid voltage up to the value defined by eq.(17).

If the limiter operates at considerable signal amplitudes, it may be unsuitable for approximating the volt-ampere characteristic of the nonlinear element by means of an exponential function. Then we must use, for example, the power approximation

$$i = \alpha u_i^n.$$

Here the differential equation which describes the transfer process in the limiter is integrated in accurate form only when the values of n are rational numbers.

Examining this problem in a general form leads to rather complex calculations (Bibl.3); however, these are greatly simplified under individual concrete conditions.

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ERROR IN DETERMINING THE Q-FACTOR ON THE Q-METER

by

I. S. Pavlov

The author establishes the hyperbolic dependence of errors on the instrument readings, when determining the quality factor of a specimen. Computation data are presented in a Table and in graph form. The proposed formulas permit some general conclusions on the accuracy of determining the quality factor with the help of a Q-meter.

Because of their simplicity and convenience in measuring within a wide range of frequencies, Q-meters are widely used in plant laboratories and in research work. However, the problem of the accuracy of measurements made with the help of the Q-meter has not been sufficiently clarified in the literature of this country.

Measuring with the help of a Q-meter may be done in parallel or in series connection of the specimen. The original instructions recommend that, in either case, the active resistance of the specimen which is being measured should not be more than three times greater or smaller than the equivalent resistance of the test circuit. Since the equivalent resistance of the circuit in parallel connection is Q times less than the active resistance of the specimen, and since, in series connection, it is Q times greater, then the measuring range will be Q^2 times greater or less. This circumstance forces us to select the specimen dimensions accordingly, and the change in geometry naturally will influence the capacitance of the specimen, which also enters the computation formulas for the quality factor.

Skanavi (Bibl.1) estimates the error in measurement $\tan\delta$ as equal to 33% in one practical example. Bogoroditskiy and Fridberg (Bibl.2) give an approximate formula for computing the absolute error $\tan\delta$ in the following form:

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$$\Delta \operatorname{tg}\delta \approx 0{,}1 \operatorname{tg}\delta + 2\cdot 10^{-4}; \qquad (1)$$

If we apply this formula to the example analyzed by Skanavi, we will obtain a relative error of 43.3%. This comparatively great error forces us to make a more careful analysis of the possible error sources.

The computation formulas for determining the quality factor of a specimen are as follows:

For parallel connection

$$Q_{x\,par} = \frac{(C_1 - C_2)\,Q_1 Q_2}{C_1 (Q_1 - Q_2)} \qquad (2)$$

For series connection

$$Q_{x\,ser} = \frac{(C_2 - C_1)\,Q_1 Q_2}{C_1 Q_1 - C_2 Q_2}. \qquad (3)$$

In both equations, Q_x is the desired quality factor of the specimen; C_1 is the reading of the test capacitor before connection of the specimen, and C_2 is the same, after connection; Q_1 is the reading of the "Q" voltmeter before connection of the specimen, and Q_2 is the same, after connection.

According to the rules known from the theory of errors, we find the relative error of the result, which is determined according to eq.(2),

$$\frac{\Delta Q_{x\,par}}{Q_{x\,par}} \leqslant \frac{\Delta C_1}{C_1 - C_2} + \frac{\Delta C_2}{C_1 - C_2} + \frac{\Delta C_1}{C_1} + \frac{\Delta Q_1}{Q_1} + \frac{\Delta Q_2}{Q_2} + \frac{\Delta Q_1}{Q_1 - Q_2} + \frac{\Delta Q_2}{Q_1 - Q_2}. \qquad (4)$$

Although the scale of the test capacitor is irregular, the capacitance in all cases can be determined with the same absolute error by using a vernier capacitor. For this reason, we may take ΔC_1 as equal to ΔC_2. Under this condition, eq.(4), after slight transformation, takes the form

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$$\frac{\Delta Q_{x\ par}}{Q_{x\ par}} < \Delta C\left(\frac{2}{C_1 - C_2} + \frac{1}{C_1}\right) + \Delta Q_1\left(\frac{1}{Q_1 - Q_2} + \frac{1}{Q_1}\right) + \\ + \Delta Q_2\left(\frac{1}{Q_1 - Q_2} + \frac{1}{Q_2}\right). \tag{5}$$

Let us introduce a dimensionless capacitance and a dimensionless quality factor, denoting

$$\frac{C_2}{C_1} = \alpha \text{ and } \frac{Q_2}{Q_1} = \beta,$$

Then, eq.(5), in a dimensionless form, will be written as follows:

$$\frac{\Delta Q_{x\ par}}{Q_{x\ par}} < \frac{\Delta C}{C_1}\left(\frac{3-\alpha}{1-\alpha}\right) + \frac{\Delta Q_1}{Q_1}\left(\frac{2-\beta}{1-\beta}\right) \cdot \frac{\Delta Q_2}{Q_2}\left(\frac{1}{1-\beta}\right). \tag{6}$$

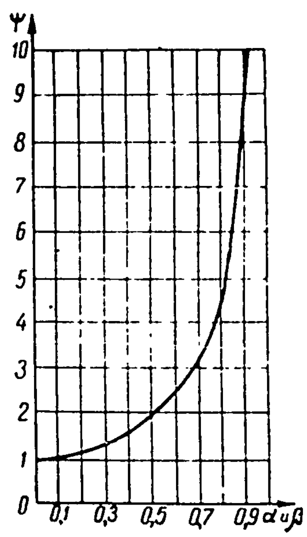

Fig.7

To simplify further computation, let us introduce the function $\psi(\alpha) = \frac{1}{1-\alpha}$ and, correspondingly, $\psi(\beta) = \frac{1}{1-\beta}$.

Then, eq.(6) may be presented as

$$\frac{\Delta Q_{x\ par}}{Q_{x\ par}} < \frac{\Delta C}{C_1}[2\psi(\alpha) + 1] + \frac{\Delta Q_1}{Q_1}[\psi(\beta) + \\ + 1] + \frac{\Delta Q_2}{Q_2}\psi(\beta) \tag{7}$$

Thus, computing the error in the result consists in finding the function ψ from the independent variables α and β. The latter may vary within the limits of from 0 to 1, while ψ increases from 0 to ∞. The graph for the function ψ is shown in Fig.1, and its numerical values are shown in Table 1.

An examination of eq.(7) shows that, other conditions being equal, the smaller

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the independent variable ψ, the smaller will be the error in the result: In other words, the greater the difference in the measured values in the test circuit with and without the specimen, the smaller will be the error in the result. This observation is unconditionally correct for measurements of capacitance; as far as the "Q" voltmeter readings are concerned, we must keep in mind the irregularity of the instrument scale.

Table 1

Value of α and β	ψ	$\psi + 1$	$2\psi + 1$
0,0	1,00	2,00	3,00
0,1	1,11	2,11	3,22
0,2	1,25	2,25	3,50
0,3	1,43	2,43	3,86
0,4	1,67	2,67	4,33
0,5	2,00	3,00	5,00
0,6	2,50	3,50	6,00
0,7	3,33	4,33	7,67
0,8	5,00	6,00	11,00
0,9	10,00	11,00	25,00
1,0	∞	∞	∞

In the same manner, we may obtain the formula for estimating the resultant error when the specimen is connected in series [see eq.(3)]

$$\frac{\Delta Q_{x\ par}}{Q_{x\ ser}} < \frac{\Delta C}{C_2}\left(\frac{2}{1-\alpha} + \frac{\alpha+\beta}{\alpha-\beta}\right) + \frac{\Delta Q_1}{Q_1}\left(\frac{2\alpha-\beta}{\alpha-\beta}\right) + \frac{\Delta Q_2}{Q_2}\left(\frac{\alpha}{\alpha-\beta}\right). \qquad (8)$$

Here β, as above, denotes the ratio of Q_2 to Q_1, while α is the ratio of C_1 to C_2. Since, in series connection, $C_2 > C_1$, α and β are, as before, less than unity. In order to use the same function ψ for computations according to eq.(8), we proceed as follows:

We divide the numerator and denominator of the fractions in eq.(8) which

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101 contain β by α and, denoting $\frac{\beta}{\alpha}$ by γ, we bring eq.(8) to the following form after slight transformation:

$$\frac{\Delta Q_{x\,ser}}{Q_{x\,ser}} \leqslant \frac{\Delta C}{C_1}\left[2\psi(\alpha) + \psi(\gamma) + \gamma\psi(\gamma)\right] + \frac{\Delta Q_1}{Q_1}\left[\psi(\gamma) + 1\right] + \frac{\Delta Q_2}{Q_2}\psi(\gamma). \qquad (9)$$

Now it is not difficult to notice the similarity in structure of eqs.(9) and (7), as deduced above.

We will show that $\gamma < 1$ and that, for this reason, the data of Table 1 may be used for computations according to eq.(9).

In actual fact, in eq.(3) $C_2 > C_1$, and the numerator is positive. Since the quality factor is positive, the denominator of eq.(3) is greater than zero, and $C_1Q_1 > C_2Q_2$. From this it follows that

$$\frac{C_2Q_2}{C_1Q_1} = \frac{\beta}{\alpha} = \gamma < 1. \qquad (10)$$

Thus, if we consider γ as the independent variable $\psi(\gamma)$, we may use Table 1 in computations according to eq.(9). It is true that there is no value for $\gamma\cdot\psi(\gamma)$ in the Table, but these data are easy to obtain by subtracting 1 from the figures in the ψ column. Actually, it is relatively easy to check the fact that

$$\gamma\cdot\psi(\gamma) = \gamma\frac{1}{1-\gamma} = \frac{1}{1-\gamma} - 1 = \psi(\gamma) - 1.$$

The information in the calculations for adding up a simple tabular function, in each individual case, permits computing without particular difficulties the resultant error in determining the quality factor on a Q-meter. In addition, eqs.(7) and (9) make it easy to come to certain general conclusions. For example, we may show that when the relative error in measuring the capacitance and quality factor of the circuit is the same, the error in series connection is greater than in parallel connection. From eq.(10) it is clear that $\gamma > \beta$ and that, by the very nature of ψ, we have $\psi(\gamma) > \psi(\beta)$. For this reason, when the errors in the quality factor are relative, the multipliers in eq.(9) are larger than in eq.(7). When the error is relative, the multiplier in eq.(9) is greater than in eq.(7) for the reason that (and this is not difficult to confirm)

$$|\psi(\gamma) + \gamma\psi'(\gamma)| > 1$$

(with the exception of the case where $\gamma = 0$, which does not occur in practice).

In addition, it is evident from eq.(9) that, in series connection, in contrast to parallel connection, the errors in measuring the capacitance and quality factor are not independent quantities.

Article received by the Editors 5 March 1956

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THE AMPLIFIER WITH MIXED FEEDBACK COUPLING

by

I. A. Suslov

In No. 7 of "Radiotekhnika" for 1955, and article by M.M.Ayzinov "Impulse Amplifier with Two-Channel Feedback Coupling" was published (Bibl.1). The author asserts that the two-stage circuit he proposes permits an amplification 12 times greater than with a two-stage amplifier with a simple correction circuit, and he declares that this hookup "will find widespread practical application". However, a closer scrutiny of the article shows that it contains a number of mistakes.

The fundamental equation of the article, eq.(1), for the amplification factor (Bibl.1) is erroneous. It is easy to demonstrate that this formula does not correspond to the circuit being examined. Let us introduce the following symbols: $\dot{u}_1$ is the voltage of the open-circuit conditions at the output of the signal source; $\dot{u}'_1$ is the voltage at the amplifier input (Fig.1); and u_2 is the voltage at the amplifier output. M.M.Ayzinov, as follows from the schematic he gave (Bibl.1) and from the fact that he does not take into account the output resistance of the signal source, defines the amplification factor as $\frac{\dot{u}_2}{\dot{u}'_1}$. In the terms of the article (Bibl.1), he should obtain

$$K = \frac{\dot{u}_2}{\dot{u}_1} = \frac{S_1 S_2 R^2 R_2 - S_1 R^2 + i\omega C_2 R(R + R_2) + (i\omega)^2 R^2 R_2 C C_2}{R_2 + 2R + S_2 R^2 + i\omega R(R + R_2)(C + C_2 + C_3) + (i\omega)^2 C (C_2 + C_3) R^2 R_2}. \quad (1)$$

If, in order to make a check test, we assume here that $C_2 = \infty$, we will obtain $K = 1$. From the schematic in Fig.1 (Bibl.1) it is evident that, when $C_2 = \infty$, the amplifier input is connected to the amplifier output and $K = 1$. If we assume that all the spurious capacitances are infinitely large, we obtain

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$$K = \frac{\frac{1}{C_3}}{\frac{1}{C_2} + \frac{1}{C_3}},$$

i.e., the circuit is a capacitance divider for the applied $\dot{u}'_1$ voltage. But M.M. Ayzinov's formula does not yield these results, which directly follow from the schematic given.

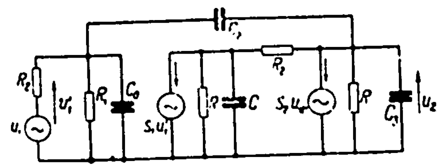

Fig.1

The expression $K = \frac{\dot{u}_2}{\dot{u}'_1}$ does not take into account the effect of the output resistance of the signal source and, in fact, does not take into account the positive feedback which encompasses both stages.

Therefore, to fully analyze the operation of the circuit we still have to examine the signal source system, namely the input resistance of the amplifier. It is simpler, however, to use the different approach of directly defining the amplification factor for feedback

$$K_{oc} = \frac{u_2}{u_1}.$$

This coefficient may, for example, be found by solving the system of equations of the aggregate potentials for an equivalent amplifier circuit (Fig.1)

$$K_{oc} = \frac{\frac{1}{R_2}\begin{vmatrix} S_1, & \frac{1}{R} + \frac{1}{R_2} + i\,\omega C \\ -i\,\omega C_2, & S_2 - \frac{1}{R_2} \end{vmatrix}}{\begin{vmatrix} \frac{1}{R_i} + \frac{1}{R_1} + i\,\omega(C_0 + C_2), & 0 & -i\,\omega C_2 \\ S_1, & \frac{1}{R} + \frac{1}{R_2} + i\,\omega C, & -\frac{1}{R_2} \\ -i\,\omega C_2, & S_2 - \frac{1}{R_2}, & \frac{1}{R} + \frac{1}{R_2} + i\,\omega(C_2 + C_3) \end{vmatrix}}$$

$$= \frac{H + i\,\omega L + (i\,\omega)^2 M}{P + i\,\omega Q + (i\,\omega)^2 R + (i\,\omega)^3 T}. \qquad (2)$$

M.M.Ayzinov's formula has no similarity to eq.(2), even if we assume in eq.(2) that $C_0 = 0$*. The numerator contains a term of the first degree in reference to $i\omega$; the coefficients for degrees of $i\omega$ in the numerator and the denominator are completely different.

Once he has obtained an incorrect formula for K, the author M.M.Ayzinov immediately commits another error. He assumes that SR = 1. This is permissible in simple cases where SR may be eliminated as a common factor before the expression for K, so that the coefficients for $i\omega (i\omega)^2$ etc. will not depend on SR. In other cases, assuming that SR = 1 will lead to a change in the coefficients for the degrees of $i\omega$, and consequently will lead to an arbitrary change of form in the frequency and phase characteristics. The coefficients for the degrees of $i\omega$ in eq.(2) depend upon SR, and the simplification made by M.M.Ayzinov is impermissible. Equation (2), for K_{OC} takes on an even simpler form if we assume that $SR_2 = 1$. But then the amplification at mean frequencies is equal to zero, and it becomes evident that arbitrary simplifications of this sort are impermissible.

As a result of his simplification, M.M.Ayzinov obtains

$$K(p) = \frac{K_1(p_1)}{N} \quad \frac{1 + Gp}{1 + Dp + Ep^2 + Fp^3}, \tag{3}$$

where

$$p = i\omega CR.$$

Here only N and G are computed correctly; mistakes were made in computing the coefficients D, E, and F.

Having further obtained the three equation system

*M.M.Ayzinov does not take into account the capacitance of C_0. But it is of the same order as the other spurious capacitances of the circuit. Thus, there is no reason for disregarding it.

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$$\frac{1}{A} = \frac{an^2 d\delta}{a+3}, \quad \frac{B}{A} = \frac{nd\delta(2+a)+an^2}{a+3} \text{ and } \frac{V}{A} = \frac{2n(1+a)+3\delta d}{a+3} \qquad (4)$$

for correction parameters a, d, and δ, where the coefficients A, B, and V are expressed by the roots $x_1 = -\alpha_1 \pm i\omega_1$ and $x_2 = -\alpha_2$ of the characteristic equation of the transmission factor, M.M.Ayzinov asserts that from these equations we can find a, d, and δ. This assertion is incorrect. From the first equations in the system (4) we really can find a and δd. The third equation in the system (4) once again gives us δd, if a is known. If this value of δd differs from the value found previously, then the equations in the system (4) are incompatible; if this coincides, we cannot find δ and d separately. Thus the third equation in the system (4) only gives us the known limitations for the conditions of physical practicability. The author admits serious errors in solving the equations in the system (4), and as a result of this he loses part of the conditions of physical practicability of the parameters and obtains an incorrect formula for the parameters.

The "conditions for realizing the amplifier circuit", $0 < \alpha_1 < 1$, $0 < \omega_1 < 4$, and $1 < \alpha_2 < \infty$, as cited in the article (Bibl.1), contradict the "condition of physical practicability" which the author has just obtained:

$$2{,}25\,B > 5{,}08\,A + 1{,}5. \qquad (5)$$

Thus, the graphs of the transfer characteristics, shown in Fig.3 of the article, are constructed for $\alpha_1 = 1$, $\omega_1 = 4$, $\alpha_2 = 4$, and $\alpha_1 = 1$, $\omega_1 = 4$, $\alpha_2 = 2$. In the first case, B = 6 and A = 68 and in the second, B = 4 and A = 34. Here eq.(5), evidently, is not satisfied, and the parameter a turns out to be an imaginary quantity, which is incompatible with its physical sense ($a = \frac{R_2}{R}$). It turns out that these transfer characteristics were constructed by the author for an amplifier which is "realizable" but "physically impracticable" (?!).

In the conclusion of the theoretical part of the article, the author cites a formula for the "maximum amplification factor" (at mean frequencies, evidently), 10 which he uses for demonstrating the advantages of his schematic. This formula is also computed incorrectly and, in addition, contradicts the general expression for the amplification factor as cited in the beginning of the article.

The graphs in Figs.4, 5, and 6 of the article - they correlate the ejection V and the generalized time of accumulation τ with α_2 and ω_1 (Figs.4 and 5), and also inter connect τ and V - are contradictory. Thus, for the conditions under which the transfer characteristic 1 in Fig.3 of M.M.Ayzinov's article was constructed, we obtain from Fig.4 a curve of $\tau = 0.25$, from Fig.5 a curve of $\tau = 0.8$, and from Fig.6 a curve of $\tau = 0.44$.

M.M.Ayzinov's article is included in his book (Bibl.2). There, all the above-indicated errors are not only retained but are supplemented by new ones. In order to show the "advantages" of his amplifier, M.M.Ayzinov compares, in Fig.16.33 of Bibl.2, graphs of the dependence of τ upon V for the circuit in question and for circuits with two correcting inductances. Curve 5 in this diagram illustrates the same dependence as the curves in Fig.6 of the article. But there is no similarity between them. The path of the latter graph indicates that, at comparatively small values for the overshoot V, the value of ι may be equal to zero, or may even be negative. It turns out that the front of a pulse which has passed through such an "amplifier" acquires no lag and even may acquire a forward slant (?!).

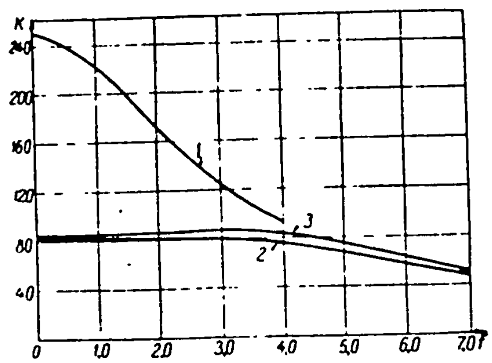

Fig.2

Let us note that the author uses three names for the amplifier he has proposed. In the heading and annotations of the article, the schematic is called an "amplifier with two-channel feedback". In the text of the article "two" is replaced by "many", and in the book we find it called an "amplifier with combined feedback".

It is strange that the results, whose practical value are emphasized by the author, were not checked experimentally by him.

The data of the article show that no such check was made. Actually, the time constant of the feedback circuit in the example cited by M.M.Ayzinov and used for his conclusions, is equal to $R_1C_2 = 19.2 \times 10^{-8}$. Therefore, the relationship $\frac{R_1}{\left|\frac{1}{i\omega C_2}\right|}$ is equal to $\omega C_2R_1 = 19.2 \times 10^{-8}\omega$. For example, at a frequency of $f = 5$ mc we obtain $C_2R_1 \approx 6$. Thus at frequencies of a few megacycles and more, almost the total voltage from the amplifier output is supplied to its input in positive phase. Let us note here that the amplifier has a high amplification ($K_o = 277$) and a pass band of 22.5 mc (the setting-up time is 1.55×10^{-8} sec). If M.M.Ayzinov had assembled such a circuit he would have discovered without much difficulty that he was dealing with the usual multivibrator.

The author of this letter checked M.M.Ayzinov's circuit on three models. The "amplifier" invariably generated relaxation oscillations which, on some models, had an approximately rectangular form and on others a form closer to sawtooth oscillations. For this reason, the capacitance of C_2 was reduced, contrary to the values obtained according to M.M.Ayzinov, so that there was no generation and so that the frequency characteristic did not rise at high frequencies. The schematic was compared with a two-stage amplifier with countercoupling, and with an amplifier with a simple corrective network; the latter amplifier had the same amplification as the circuit in question at mean frequencies of K_o when the correction parameter k equals 0.414 ("flat" characteristic).

We cite here only the data relating to the third model. This model had plate resistances of $R_{a1} = 1.65$ k-ohms, and $R_{a2} = 1.8$ k-ohms, and a feedback resistance of $R_2 = 16$ k-ohms. The transconductances of the tubes in the quiescent points were $S_1 = 8.35$ ma/v and $S_2 = 10.2$ ma/v. The spurious capacitances in the plate circuits of the stages, with "hot" tubes and with a vacuum-tube voltmeter connected at the

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amplifier output, were computed in accordance with the frequency characteristic of the amplifier with interrupted feedback (curve 1, Fig.2). These were equal to $C = 28.2$ μμf and $C_3 = 21$ μμf. The pass band of the amplifier with countercoupling ($C_2 = 0$) was equal to $f_b = 5.725$ mc when the amplification factor K_o equals 84 (curve 2, Fig.2). The value $K_o f_v = 480 \times 10^6$ corresponds to this. In the case of a "flat" frequency characteristic, an amplifier made according to M.M.Ayzinov's schematic ($C_2 \neq 0$) on the same model had $K_o = 86$, $f_v = 6.2$ mc and $K_o f_v = 530 \times 10^6$ (curve 3, Fig.2). According to M.M.Ayzinov (Bibl.2) for more difficult cond.. (a 3% ejection) we should have obtained $K_o = 227$ and $f_v = 22.5$ mc ($K_o f_v = 6250 \times 10^6$). Knowing the transconductance of the tubes in the quiescent points, we

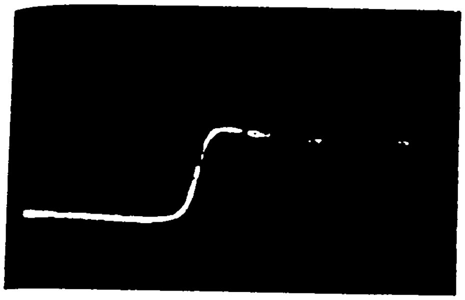

Fig.3

Fig.4

can compute the pass band of an amplifier which has a simple corrective network and which has the same amplification ($K_o = 86$) and the same spurious capacitances as M.M.Ayzinov's circuit. For the case of the "flat" characteristic, computation gives $f_v = 8.1$ mc ($K_o f_v = 696 \times 10^6$).

When the circuit of positive feedback ($C_2 = 0$) was opened, the overshoot on the transfer characteristic of the amplifier, as observed on an IPX-1 screen, was 8% (Fig.3), and when the value of C_2 corresponded to the "flat" frequency characteristic, it increased to 12.5% (Fig.4).

The data cited show that M.M.Ayzinov's circuit gives poorer results than a simple corrective network. In addition, as the author himself has noted (Bibl.2),

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a poor amplification stability is characteristic of his schematic.

Article received by the Editor 18 June 1956; after revision and arranging 9 January 1957.

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From the Editor. A letter mentioning M.M.Ayzinov's errors in his article The Amplifier with Two-Channel Feedback was also received by the Editor from B.P.Shasherin (Ural Polytechnic Institute, imeni S.M.Kirov, Sverdlovsk).

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A.G.ARENBERG

The outstanding Soviet radio specialist and Doctor of Technical Sciences, Professor Aleksandr Georgiyevich Arenberg, died on 11 March 1957, at the age of 52. The famous scientist and talented pedagogue has passed on in the fullness of his creative powers, having dedicated his entire life to the supreme service of Soviet radio engineering, especially in the field of ultrashort waves.

Having started his scientific work at almost the beginning of ultrashort wave technology, Aleksandr Georgiyevich took a creative part in its development. From his first steps to the end of his life he combined scientific with practical in-interests and strove to bring scientific attainments to the form necessary for practical satisfaction of the demands of the People's economy, the defense of our socialist native land.

A.G.Arenberg started working in 1921 in the Physics Department of Moscow State University and in 1926 transferred to the radio division of the Government Experimental Electrical Engineering Institute (now the VEI).

Aleksandr Georgiyevich was one of the most active participants in the first experiments to establish the basic principles of scattering of ultrashort waves.

In 1927 and 1928, together with B.A.Vvedenskiy and A.V.Astaf'yev, he worked out a new transceiver on the 4-m wave. With this apparatus, they conducted the first experiments to establish the quantitative laws for broadcasting ultrashort waves at distances of practical interest. Again in 1928, A.G.Arenberg took active part in research on broadcasting ultrashort waves at distances to 60 km with the transceiver at a certain height (observations were made in aerostats and airplanes).

When he finished at the MVTU in 1929, A.G.Arenberg became assistant professor

at the physics faculty of the MGU. There he later gave a course on the "Physical
100 Bases of Electrical Engineering and Radio Engineering", and in 1935 a course on the "Broadcasting of Radio Waves".

At the same time he managed the ultrashort-wave laboratory at the VEI, and here his remarkable organizatory talent and his ability to rally the collective came to the fore.

In 1934 he directed production of a stationary microwave apparatus; this system was probably one of the very first radio circuits in this range to be equipped with transition to wire lines, and to operate for a considerable length of time.

In 1935 A.G.Arenberg was awarded (without defending a thesis) the scientific degree of Candidate of Technical Sciences. In the same year he started giving his course on the broadcasting of radio waves at the Moscow Electrical Engineering Institute of Communications, and later at the Technical Engineering Communications Academy.

In 1936 A.G.Arenberg entered the Electrical-Communications Brigade, created by Academician A.V.Shuleykin, and worked on problems of the emission and diffusion of radio waves. In 1940, after defending a thesis, he was awarded the scientific degree of Doctor of Technical Sciences and the title of full Professor.

From 1942 to 1952 A.G.Arenberg, in the ranks of the Soviet Army, did instructional and scientific research work.

In 1952 Aleksandr Georgiyevich once again took up his work within the system of the AN SSSR, in the section for scientific treatment of radio-engineering problems. From 1954 to the last days of his life he managed the laboratory of the Institute of Radio Engineering and Electronics of the AN SSSR (the IRE AN) and held a chair in the Moscow Physics Institute. In addition, he took part in the work of the All-Union Congress on Radio Physics of the AN SSSR and in the work of other organizations.

Constantly combining his scientific research activity with his pedagogical

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10 activity, A.G.Arenberg published more than 60 works, both personally and in creative collaboration with other authors. Among these are the following monographs, which have obtained wide renown: "The Broadcasting of Ultrashort Waves; Radio Waveguides; and Problems in Broadcasting Ultrashort Waves", all written in collaboration with B.A.Vvedenskiy. In a few days the great final work of A.G.Arenberg will be published: "Broadcasting of Decimeter and Centimeter Waves". Everything Aleksandr Georgiyevich has written bears the stamp of his remarkable pedagogical talent. His talent as a research worker and his talent as an organizer are harmonically combined with this talent.

Side by side with his scientific and pedagogical activity, A.G.Arenberg always did a great deal of social work. He took active part in the work of the scientific-technical societies (the Russian Society of Radio Engineers, the Friends of Radio Society, the A.S.Popov Scientific-Technical Society of Radio Engineering and Electrical Communication) and he prepared reports and published lectures. The last item he had published was a brilliant report on a commemorative meeting dedicated to the memory of Hertz. From the time the journal "Radiotekhnika" was organized up to the end of his days, A.G.Arenberg was one of the most active and initiative members of its editorial staff. He was also a member of the editorial staff of the journal "Radiotekhnika i Elektronika".

A.G.Arenberg took active part in organizing and developing the society of Soviet radio amateurs, in the years from 1924 to 1928.

Aleksandr Georgiyevich trained a great number of specialists in the fields of radio physics and radio engineering. Many of them are now important scientists.

We will never forget the shining image of Aleksandr Georgiyevich, the image of a selfless and talented engineer and scientist, an outstanding organizer, a sympathetic friend, a public-spirited man of principle, an ardent Communist and patriot, and an active champion in building up a Communist society.

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IN THE A. S. POPOV SCIENTIFIC-TECHNICAL SOCIETY OF RADIO ENGINEERING AND ELECTRIC COMMUNICATION

A Plenum of the Central Administration of the NTORIE, imeni A.S.Popov was held in Moscow on January 25, 1957; in the meeting, the results of the Society's activity during 1956 and a plan of operation for 1957 were discussed.

When it had heard and discussed the report of the President of the Central Administration, V.I.Siforov, on the Society's activity in 1956, the Plenum noted the improvement in the Society's work in the current year as compared with previous years. Scientific-technical propaganda was intensified, and more conferences, consultations, cyclic and episodic lectures, seminars on new techniques, and other measures began to be held. Thus, in 1956, in Moscow and in the provinces, the Society held 522 scientific-technical conferences, consultations, discussions, and public inspections - of which 468 took place in the primary organizations. More than 31,000 persons took part in these undertakings. About 2000 reports and lectures were organized, with an audience of more than 82,000 persons. More than 220 courses and seminars were held, and about 4500 members of the Society took part in these.

However, there are still serious gaps in the activity of the Society, and these are due to the insufficient amount of organizational work done by the Central Administration and the local branches of the Society. We have still not exploited all the possibilities for creating new organizations and for attracting new members into the ranks of the Society. The Society has for the most part devoted its activity to enterprises and institutions located in the large cities. A network of primary organizations has not yet been developed in the provinces, or in a number of enterprises of the Ministries of Communications, of the Radio-Engineering Industry, and of other Ministries and Departments.

The Central Administration, and the Republican and District Administrations,

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have poorly directed the local organizations; as a result, many Councils of primary organizations undertook no decisive measures to mobilize members of the Society for solving fundamental productions problems, and have poorly spread and propagated their advanced experience.

The Plenum accepted the resolutions of the report, with concrete recommendations directed at improving the Society's activity.

The Plenum obliged all administrations of the Society to intensify their work in attracting new members into the ranks of the Society - for the most part rationalizers, inventors, production innovators, and young specialists.

The Presidium of the Central Administration, the Republican, Regional, and District Administrations, and the Revisionary Committees should increase their control on implementing the decisions and recommendations of the consultations and conferences of the Society's organizations. We must work out a system for active control over the recommendations of the Society directed at Ministries and Departments. In order to increase practical aid for departments and enterprises in developing the rationalizer and inventor movement, the Plenum recommended that all administrations of the Society, as well as the primary organizations, take a direct part in all actions by economic organizations and trade union organizations in the field of rationalization and invention. It decided to organize discussion of plans on standards, norms, and terminology in the field of radio engineering and electric communications, and also decided to request the directors of the corresponding organizations to send material to the Society for discussion. It decided to request the directors of ministries and departments, as well as directors of enterprises, to make reference to the Society in orders and other documents in which the Society's suggestions are used; this will lead to a state where the organizations of the NTORIE, imeni A.S.Popov are more responsible for their enactment.

The Plenum of the Central Administration sanctioned the activity schedule for the Society for 1957. In this connection, plans were made to hold, in the

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provinces, a series of scientific-technical conferences and consultations devoted to problems in the development of means of electric communications and radiofication for the coming years. The plan includes conferences on exchange of experience in using a television broadcasting network (television centers and television enterprises for public service). We will also organize scientific-technical conferences on the technical problems in television broadcasting and distant reception of television. For discussion of the problems in automation and mechanization of production, we have provided conferences on the problems involved in automation of control processes, on the application of conveyer methods in industry, and on problems met in the use of printed circuits and small-size parts in enterprises of the radio-engineering industry.

One important undertaking of the Society for 1957 will be the All-Union A.S. Popov Prize Competition for better work in the field of radio engineering, and also the All-Union Competition for better suggestions in the field of new techniques and technology of production.

The plan gives a great deal of attention to the problems involved in the exchange of experience in rationalizer and inventor work, and in application of advanced work methods.

We have provided for the Society's participation in working out problems of terminology, and also in discussing plans on standards and norms in the field of radio engineering and electric communications.

A considerable amount of work will be done in 1957 toward raising the scientific-technical level of the members of the Society.

Plans were made to hold an All-Union Scientific Session, dedicated to Radio Day, in Moscow in May of this year; scientific-technical conferences will be held in the provinces.

In 1957 there will be considerable intensification of work on setting up new organizations and increasing the ranks of the Society.

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Conference on Problems in Long-Distance Ultrashort Wave Broadcasting*

From 28 to 30 January 1957, the Society held a conference on the problems involved in long-distance ultrashort wave broadcasting; the conference was held in Moscow jointly with the All-Union Scientific Council on Radio Physics and Radio Engineering of the AN SSSR, and the Institute of Radio Engineering and Electronics of the AN SSSR. More than 180 specialists from Moscow, Leningrad, Tomsk, Gor'ky, Odessa, Taganrog, Rostov, and other cities of the nation took part in the work of the conference.

The following papers were read at the conference: A.N.Kazantsev's "On Scatter of Microwaves in the Ionosphere", V.A.Bubnov's "Reception of Signals from the Khar'kov Television Center and Ultrashort Wave Frequency Modulation of Transmitters beyond the Horizon", A.I.Khachaturov's "Some Results of Preliminary Observations of Extreme-Distance Broadcasting of Radio Waves of the Meter Range", S.K.Sotnikov's "Long-Distance Television Reception in Moscow", Ya.L.Al'pert's "Scatter of Radio Waves in the Ionosphere and Long-Distance Broadcasting of Ultrashort Waves", B.N. Gershman's "Turbulent Scattering and Diffusion of Radio Waves by the Ionosphere", S.F.Migkotan's "An Investigation into the Irregular Structure of Ionospheric Layers in Height during Frequency-Dispersed Reception", D.M.Vysokovskiy's "Some Problems in the Theory of Scatter of Ultrashort Waves in the Troposphere", P.P.Biryulin's "An Equation for Computing Fluctuations in the Wave Field", V.A.Zverev's "On the Problem of a Method for Computing the Diffusion of Radio Waves into Accidental Heterogeneities", M.V.Boyenkov's "On Long-Distance Ionospheric Diffusion of Ultrashort Waves", L.A.Drachev's and Yu.V.Berezin's "An Investigation of the Heterogeneous

*Information on the work of the conference will be given in the next issue of the Journal.

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Structure of the Ionosphere with the Help of Recording Variations in the Phase Path of a Reflected Radio Pulse", A.A.Semyenov's and G.A.Karpeyev's "An Investigation into the Character of the Rapid Drowning of Radio Signals When Broadcast on Near-Earth Routes of Mean Duration", L.Ya.Kazanov's and A.N.Lomakin's "Measuring the Heterogeneities in the Dielectric Permeability of the Air in the Troposphere".

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EIGHTH SESSION OF THE PLENARY CONFERENCE OF THE INTERNATIONAL CONSULTING COMMITTEE ON RADIO (ICCR) IN WARSAW

The decision to set up an International Consulting Committee on Radio Communications (ICCR) was made at the Washington World Conference on Radio in 1927. The task of the ICCR was to study proximate technical problems in international communications as they were brought up by administrations and commercial radio committees, and to come to conclusions on them.

Delegations from 40 governments, including the USSR, took part in the first meeting of the ICCR (The Hague, 1929); representatives of 32 governments and dominions took part in the second (Copenhagen, 1931); 22 governments and 8 international organizations were represented at the third meeting (Lisbon, 1934). The USSR was not represented. A total of 29 nations and 5 international organizations took part in the fourth meeting of the ICCR (Bucharest, 1937).

At the Cairo World Conference on Radio Communications (1938), the tasks of the ICCR were broadened: not only questions of technology, but also questions of exploitation, were put within the scope of the ICCR.

At the radio conferences in Atlantic City in 1947, new radio rules were laid down, and the terms of convocation of plenary meetings of the ICCR were changed (every 2 years instead of 3).

As a result of the work of the fifth meeting of the ICCR (Stockholm, 1948), 13 new committees were set up. The meeting accepted 35 recommendations and received 33 problems for study.

The sixth plenary meeting of the ICCR (Geneva, 1951) accepted 50 recommendations, 44 problems subject to study, and 38 programs of study.

The seventh meeting of the ICCR (1953) was held in London. Delegations from 38 countries took part in it, as well as representatives of private commercial and

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industrial companies and observers from international organizations. The Soviet delegation took an active part in the work of the session's plenary conferences and in nine investigation committees, and it published two reports. In all, the meeting made 170 decisions.

The eighth session of the Plenary Conference of the ICCR was held in Warsaw in 1956. Forty countries participated: Albania, Argentina, Australia, Austria, Belgium, the Byelorussian SSR, Bulgaria, Hungary, Venezuela, Holland, the German Federal Republic, Denmark, Canada, Egypt, Spain, the USA, Finland, France, India, Ireland, Japan, Laos, Monaco, Norway, New Zealand, Pakistan, Poland, Yugoslavia, the Ukrainian SSR, Rumania, England, Sweden, Switzerland, Syria, Czechoslovakia, Turkey, the Union of South Africa, the USSR, and France's overseas territories.

In addition, a Formosan, invited by the secretariate of the ICCR, participated as "representative" of China. In this connection, the Soviet delegation made a declaration protesting against the invitation of the Formosan and proposing invitation of a representative of the Chinese People's Republic.

From the German Democratic Republic, eight observers, included in the staff of the OIP delegation, took part in the session.

The 11-man Soviet delegation was headed by the acting Minister of Communications of the USSR, Z.V.Topuria.

In accordance with established tradition, the chairman of the eighth session was the representative from the host country, Professor Shul'kin.

At the first plenary conference of the session, four special committees were set up: a committee to choose a director for the ICCR, an editorial committee, a finance committee, and a committee to give technical aid to underdeveloped countries.

One of the most important problems at the eighth session was the problem of electing a new director of the ICCR to replace Professor van der Pol who was retiring as of 1 January 1957. Six candidates were chosen for the post of director of

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the ICCR. In the third round of voting Metzler (Switzerland) was elected director of the ICCR by a majority of votes, with the support of the USSR and the countries of People's Democracy; he is the chairman of the first committee of the ICCR, and is an official in the radio and telegraph service of the Postal and Telegraph Ministry.

Some general and organizational problems were also decided upon at the first plenary conferences. Then the work was transferred to the investigation committees. Final discussion and approval of the recommendations and reports prepared by the committees was done in the concluding plenary conferences.

The Work of the Investigation Committees

At the eighth session of the ICCR work was in progress by the following investigation committees:

Committee No. 1 - transmitters; committee No. 2 - receivers; Committee No. 3 - general systems and theory of communications; Committee No. 4 - the broadcasting of surface radio waves; Committee No. 5 - tropospheric scattering of radio waves; Committee No. 6 - ionospheric scattering of radio waves; Committee No. 7 - standard frequencies and time signals; Committee No. 8 - international control; Committee No. 9 - general technical problems; Committee No. 10 - radio broadcasting; Committee No. 11 - television; Committee No. 12 - tropical radio broadcasting; Committee No. 13 - problems of technical operation; Committee No. 14 - terminology; Committee on giving technical aid.

1. The Investigating Committee No. 1 is concerned with the study of technical problems relating to transmitters (bandwidth of the emitted frequencies, stability, jamming of undesirable emissions). The basic document, in accordance with which discussion and treatment of the various problems were held, was a report by the chairman of Committee No. 1, Metzler. Four documents on the problems of Committee No. 1 were presented from the USSR. In all, the Committee examined about 100 documents.

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2. Examination of the material of Committee No. 1 was divided among three subcommittees: Subcommittee 1-A - emission spectrum, bandwidth, Chairman Lochar (France); Subcommittee 1-B - frequency modulation, Chairman Burns (England); Subcommittee 1-C - stabilization of frequency and harmonics, Chairman Archukh (Poland).

The preparation of resolutions was taken care of by nine working groups, three for each subcommittee.

Our representatives in Committee No. 1 took part in five working groups: 1-A-2, 1-B-1, 1-C-1, 1-C-2, and 1-C-3.

3. Working group 1-A-1 prepared a report on the selection of a type of manipulation which occupies a minimum bandwidth and sets up minimum disturbances outside the occupied band. Twelve papers were examined in the report; these included the papers by Gabor, those published earlier as well as up-to-date investigations. From these papers it follows that a $\sin^2$ signal form is evidently the best, although still more favorable signal forms, not practically realizable, are theoretically possible.

As was noted by the Committee, the report may play an important role in the work of preparing material for the next plenary meeting of the ICCR, at which we propose to examine recommendations on the use of signals with a more economical spectrum in telegraph transmission and in television. A study of this problem merits the most serious attention.

4. Working group 1-A-2 examined methods for measuring the bandwidth occupied by emissions of a different type - chiefly of a frequency-keyed signal.

Particularly interesting were the Polish delegation's reports on an instrument developed for measuring the band, and the Japanese delegation's report on measurements made of the bandwidth of signals of different form.

As a result of study of a series of documents, including the one presented by the Soviet delegation, the working group brought up the new problem of a change in the definition of bandwidth, as it was given in the radio rules in Atlantic City,

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inasmuch as none of the proposed instruments was able to measure the amplitude of spectrum components outside the band.

The new definition, which retains the principle of 99% power content in the emitted band, excludes definition by the amplitude of emissions outside the band.

5. Working group 1-B-1 examined the problems involved in "frequency keying and telegraph distortion". The aim of the study of the problem of frequency shift was to fix standardized values of frequency separation in frequency keying. The document which was prepared by the group and accepted by the plenary assembly, provides for advantageous use of frequencies of 1000, 500, 400, 250, and 200 cycles for four-frequency keying.

6. Working group 1-B-2 prepared a recommendation on single-channel frequency telegraphy, where for international exchange it provided for the use of a frequency separation of 500 cycles, corresponding to our accepted standard. Frequency separation of 250 and 1000 cycles were provided in the recommendation on four-frequency telegraphy, and they may also be used in single-channel frequency telegraphy work with one correspondent, i.e., at substantially the same FT.

Then the group worked out recommendations on the frequency of depression and release (these are in accord with our accepted order of operation) and a report on the use of operational order in different codes.

7. Working group 1-C-1 examined the problem of harmonics and undesirable emissions set up by transmitters. As a result it worked out a recommendation, accepted by the plenary assembly, in which it was established that after the new radio rules for transmitters operating in the 10-kc to 30 mc range are accepted, which should be in 1959 (allowing three years for new transmitters and five for old ones), we should introduce new tolerances for harmonics and spurious emissions.

All harmonics and undesirable emissions in the 10-kc to 60-mc range, in the power supplied to the antenna, should be 40 db lower than the power of the fundamental frequency and should in no case exceed 200 mw, without its becoming necessary

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to reduce this level to below 10 mw. For harmonics and undesirable emissions in the
100 frequency band above 60 mc from transmitters operating in the 10-kc to 30-mc range the level should not exceed 40 db or 25 mw, but it may be over 10 mw. The problem of the number of harmonics and undesirable emissions in transmitters operating in the 60 to 235 mc range should be studied.

Then recommendations were made of proposals on measuring methods and utmost improvements in the construction of transmitters. Although the term for concrete application of this recommendation is long enough (six years for new transmitters and eight years for old ones), work in this direction should be provided for in the technical specifications for new transmitters and in the plans of institutes and branch laboratories on transmitters in use.

8. Problems of frequency stabilization in transmitters were examined by the working group 1-C-2. We must note that the work of this group attracted a great amount of attention from the delegations from industrial countries.

The following positions were accepted upon recommendation:

a) the new frequency-stability tolerances go into effect 3 years (for new transmitters) and 5 years (for old transmitters) after they are made part of the radio rules, which should be reviewed by the Administrative Conference in 1959, i.e., for 1962 and 1964, respectively;

b) the tolerances for frequency deviation should apply to stations of international service, and also to stations whose broadcasts may set up disturbances in other countries.

Under these conditions, the following tolerances were accepted:

c) B range (535 to 1605 kc) - 10 kc.

D range (4000 to 30,000 kc) - for more than 500 w - fixed

tolerances	0.0015%
for under 500 w	0.005%
shore and aeronavigational	0.005%

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over 5 kw	0.0015%
for radio broadcasting	0.0015%
E range (30 to 100 mc), fixed tolerances up to 200 w	0.02%
for over 200 w	0.003%
for television	1000 cycles
for ultrashort wave F.M. broadcasting	0.002%
for radio relay	0.02%
active up to 5 w	0.005%
active over 5 w	0.002%
F range (100 to 500 mc), active maritime tolerances	0.005%
for a 156.8 mc portion	0.002%
over land	0.002%
for radio relay	0.01%
for television	1000 cycles
ultrashort wave FM broadcasting	0.002%
G range (500 to 10,500 mc)	
radio relay lines in recent years	0.05%
in future years	0.03%

The recommendation was accepted unanimously.

We are told that these tolerances should be included in the technical specifications for planning new apparatus beginning with 1957 and that they should also be reflected in the plans of scientific-research institutes and laboratories for dealing with proposals on apparatus in operation.

9. On the problem of "stoppage of undesirable emissions from industrial devices", work group 1-C-3 came to the conclusion that it is not expedient to continue this work within the system of the ICCR. The assembly accepted the recommendation that all problems connected with the study of methods for eliminating radio interference and with their measuring be turned over to the IEC (International

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Electronics Commission) and its CISPR committee, which deal with these problems. It is also proposed that the IEC committee study problems involved in the necessary protective relationships in all ranges (not only those of radio broadcasting).

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For this committee, the group prepared an investigation program, which included proposals of the representative of the Soviet delegation on the necessity of basing norms on a theoretical analysis of the statistical principles of the transmission factor between the sources of interference and the receiving antenna.

The work of the first committee was done under businesslike conditions, with the result that all problems of the committee were decided without arguments or voting in the plenary conferences. At the same time, all accepted documents are in accordance with the proposals of the Soviet delegation.

Investigating Committee No. 2

The Investigating Committee No. 2 is concerned with studying the stability, sensitivity, and selectivity of receivers, with determining their quality factors, and with studying the improvements to be made in receivers so as to solve in the best way possible the problems in the field of radio communications. At the Eighth Plenary Assembly, this committee was headed by Abadi (France).

Committee No. 2 formed the following subcommittees:

Subcommittee A on problems of sensitivity, selectivity, and stability of receivers (Chairman Kilvington, England); Subcommittee B on problems involved in spurious emissions from receivers and in the effect of interference on radio receivers (Chairman Edzhidi, Italy).

Subcommittee A, in turn, split into groups to study: sensitivity of receivers (Chairman - van der Vik, Holland), selectivity of receivers (Chairman Krongeger, West Germany), and stability of receivers (Chairman Edzhidi, Italy).

The results of the work of the Investigating Committee No. 2 consist basically in the following:

To measure the sensitivity, selectivity, and stability of radio broadcasting

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receivers with amplitude and frequency modulation, and also of television receivers, the committee recommends that the definition and methods worked out by the IEC be used as basis.

The Committee inspected a recommendation on noise and sensitivity of receivers, which was approved by the Seventh Plenary Assembly. The new text of the recommendation contains definitions of sensitivity for radio broadcast receivers and television sets; these definitions were based on proposals of the IEC. Proceeding from signal distortions at the receiver output, the committee made more precise the definition of maximum sensitivity which can be used for telegraph receivers.

It studied a recommendation of the Seventh Plenary Assembly on the frequency stability of radio receivers; it gave some additional recommendations for increasing the stability of receivers, such as the desirability of separating the tubes of the heterodyne and the frequency changer and using parts which operate reliably under different external conditions, and also the exclusion of range commutators in the heterodynes of multirange receivers, by using multiplication of frequency instead of commutation. The Committee recommended using methods of measuring the effects of quasi-pulse interference upon receivers, and it recommended devices for measuring these effects.

The Committee worked out a new problem whose aim is to give a more precise definition of the question what types of receivers, besides radio-broadcast and television receivers, will be influenced by quasi-pulse interference as to their maximum usable sensitivity, and also to give a better definition of the quantitative aspect of the effect of pulse interference, and methods for evaluating this effect.

It worked on a new project to define the extent to which the methods of measuring spurious emissions in receivers, as worked out by the IEC, may be used for all types of receivers, and not just radio-broadcast or television receivers, and also the extent to which the methods of measuring these spurious emissions, as worked out by the IEC, are suitable for all types of receivers.

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In the study by Committee No. 2 of the problem of selecting an intermediate frequency for superheterodyne receivers, no concrete recommendations were worked out. The Committee limited itself to publishing a report which pointed out the fact that it is impossible to select any one value for the intermediate frequency which would be suitable in the same way for the various parts of the European zone. It recommended continued study of problem No. 78, posed by the Seventh Plenary Assembly, while paying particular attention to the choice of an intermediate frequency for maritime receivers, upon whose operation the safety of human lives depends.

Investigating Committee No. 3

Committee No. 3 (Director Van Dyuren, Holland) examined problems of the theory of communications, the use in radio communications of new noiseproof systems with automatic repetition (ARQ-systems), the characteristics of rhombic antennas, and the norms for protective relationships for various types of operation.

This committee was subdivided into 3 subcommittees: III A (Chairman Cook, England) - on the characteristics of antennas and the norms for protective relationships in the communication channels; III B (Chairman Lenkowski, Poland) - on the theory of communications; III C (Chairman Boulet, France) - on the use of the five-unit code in radio communications.

In the theory of communication, the question submitted for study was how to make practical modifications in the existing systems, so as to improve transmission of information, and particularly in the systems which have direct and return channels.

The study program proposed examining all useful codes and studying new codes which lead to economy in bandwidth or in time of transmission for a given quantity of information without changing the quality of transmission. It also proposed studying, jointly with the ISRU* (for footnote see next page), all problems in the theory of communications which are most suitable for practical application.

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The Committee accepted a recommendation defining a quantitative unit of information, and a recommendation in which the Dutch administration, together with other administrations, was entrusted with publishing annually a bibliography of works on the theory of communications as they appear in different countries. All documents of the committee on communication theory, dealing with actual results, were accepted unanimously. The committee heard with interest Prof. V. I. Sifirov's report "On Binary Coding" and accepted it as the USSR's contribution to the work of the Investigating Committee on communication theory. The Committee also highly praised the USSR's report "Protection from Interference in Systems with Correcting Codes", heard with great interest "Norms for Industrial Interference", which was presented by the Soviet delegation, and decided to send the norms to the International Committee on Radio Interference.

On the question of the use, in radio communications, of noiseproof systems, the Committee made a recommendation, submitted a report, and read the text of a new project. As a preferred noiseproof system, the recommendation proposes the ARQ semi-sign system, which was worked out by the chairman of Investigating Committee No. 3, Van Dyuren. As a supplement to this recommendation, the Committee accepted the text of a new project which proposes studying the nature of distortions as a function of the signal-to-noise ratio, the nature of the interference, the conditions of its diffusion, the types of transmission, etc.; it also proposes studying the practical value of various types of correcting codes, and defining the systems with correcting codes which permits an electrical transit of the correspondence. This last point in the project was included in the proposal of our delegation and will be studied jointly with the ICCR.

The report examines the causes of interference in radio circuits and comes to

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*The International Scientific Radio Union. The Radio Council of the AN SSSR has been a member of this Union since 1955.

the conclusion that synchronous systems are useful when the speed of operation is great. All documents on noiseproof systems were accepted by our delegation.

With respect to antennas, the old recommendation gave the values of the amplification factor for rhombic antennas in the direction of the main lobe, while in all other directions it considered the amplification of a rhombic antenna equal to 0 db. The new recommendation reviews the values of the amplification factor in the direction of the main lobe and also gives the amplifications in the direction of the side lobes; in all other directions it reduces the antenna amplification to -3, -6 db.

With regard to the norms for the protective relationships, the Committee, without sufficient material, began a rigid inspection of the norms for the protective relationships between signal and interference for different types of operation, with and without taking fading into account.

In view of the importance of the problem of selecting the norms for protective relationships, and in view of the absence of necessary investigations into this problem, and also in view of the fact that the ICCR still does not have a sufficient amount of material confirming the accepted norms, the delegation from the USSR reserved its opinion on these problems.

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NEW BOOKS

M.N.Andrievsky. Construction of Generators of Microwaves and Ultrashort Waves. Oborongiz, Moscow, 1956, 132 pp. Price 5 r. 45 k.

The book describes the design of superhigh-frequency generators constructed on symmetrical two-wire lines and cavity vibrators; It gives a method for planning the various structural elements and presents numerous examples of their structural variants.

The book is intended for engineers working on microwave and ultrashort-wave generator projects, and for advanced students in radio-engineering faculties.

M.I.Vitenberg. Computing Electromagnetic Relays for Automatic and Communication Equipment. Gosenergoizdat, Moscow-Leningrad, 1956, 411 pp. Price 14 r. 50 k.

The book is devoted to the problems involved in the theiry and computation of DC and AC electromagnetic relays for automatic and communication systems. It gives an account of analytic and grapho-analytic methods for computing electromagnetic relays, describes their construction, and presents experimental material for the basic types of automatic and communication relays.

The book is intended as a guide for engineers and technicians working in the field of computation and construction of automatic and communication relays and electromagnetic mechanisms, and as a study aid for students in the higher universities and faculties.

S.D.Gvozdover. Theory of Superhigh-Frequency Electronic Instruments. Gostekhteoretizdat, Moscow, 1956, 527 pp. Price 10 r. 90 k.

In the first Chapter the book, which contains 12 Chapters, gives the elements of the electrodynamics of cavity resonators. In Chapters 2 to 6 it examines the flat diode: its static characteristics, the effect of variable

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voltage on it, the electronics of the diode in a case where the effect of the 100 cavity charge is negligibly small, and also the effect of transit effects on noises in the flat diode.

In Chapter 7, the book examines high-frequency amplification of radio signals with the help of a triode. Chapters 8 to 12 are devoted to the general theory of single-circuit klystron generators, to the theory of the deflector klystron, to an introduction to the theory of the multi resonator magnetron, to the theory of the traveling-wave tube, and also to noises in the electron gun, and the sensitivity of the traveling-wave tube.

Tables and graphs of functions encountered in the theory of the diode, and Tables of functions for the theory of the traveling-wave tube, are given in the appendix.

The book has been accepted by the Ministry of Higher Education as a study aid for higher institutions of learning.

R.Bozort. Ferromagnetism. Foreign Literature Publishing House, Moscow, 1956, 784 pp., 1777-item bibliography. Price 49 r. 75 k.

A graphic presentation of theoretical ideas on the most important phenomena and processes in ferromagnetic metals and alloys; a description of numerous magnetic alloys, their properties, their characteristics, methods for obtaining them, etc.

The book is intended for physicists - scientific workers and engineers, active in the field of ferromagneticism and the use of magnetic materials.

The book includes an ample bibliography of foreign literature from 1842 to 1951.

Electrophysical Properties of Germanium and Silicon. An anthology of translations edited by A.V.Rzhanov. "Sovetskoye Radio" Publishing House, Moscow, 1956, 389 pp. Price 16 r. 50 k.

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The anthology presents the material of reports on semiconductors read at the Amsterdam conference in June 1954, as well as a number of other papers published from 1953 to 1955.

The anthology is intended for physicists and engineers working on semiconductors.

A.A.Kharkevich. Nonlinear and Parametric Phenomena in Radio Engineering. Gostekhteoretizdat, Moscow, 1956, 184 pp. Price 6 r.

The book is a short and readily accessible theoretical introduction to nonlinear radio engineering; it refers to such all-important radio engineering processes as generation of electric oscillations, frequency multiplication and division, rectification and detection, and frequency modulation and change.

The book can serve as an aid for students of the theoretical fundamentals of radio engineering. It may also be helpful to radio engineers.

I.G.Malkin. Some Problems in the Theory of Nonlinear Oscillations. Gostekhteoretizdat, Moscow, 1956, 491 pp. Price 6 r.

The book solves a number of problems in the theory of nonlinear oscillations, with the help of the "small-parameter method". It presents the theory of periodic and quasi-periodic oscillations in quasi-linear systems with one and many degrees of freedom, the theory of periodic and quasi-periodic oscillations in systems which are near to arbitrary nonlinear systems, and also the theory of free and forced oscillations in quasi-harmonic systems, i.e., in systems described by linear differential equations with periodic coefficients. Here a great deal of attention is devoted to the problem of the stability of the oscillations.

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